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Stack Tests at Kennecott Copper Corp. Hayden, Arizona Smelter

Acurex Corp, Mountain View, Calif Aerotherm Div

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STACK TESTS AT KENNECOTT COPPER CORP. HAYDEN, ARIZONA SMELTER

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In August and December 1976 at the request of EPA, Region IX, Envorcement Division, the Aerotherm Division of the Acurex Corporation conducted a series of air pollutant mass emissions tests at the Ray Mines Division copper smelter of the Kennecott Copper Corporation located in Hayden, Arizona. The tests were conducted at the reverberatory furnace stack in August 1976 and at the sulfuric acid plant stack in December 1976. Tests for particulate matter (Method 5), sulfur dioxide and sulfuric acid (Method 8) were conducted at each location using a combined sampling train. In addition two tests for "condensable particulate matter were conducted at the reverberatory furnace stack using the combined Method 5 and 8 sampling train with an instack filter added.

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SECTION 1

INTRODUCTION

At the request of EPA Region IX, the Aerotherm Division of Acurex Corporation undertook a series of stack tests at the Kennecott Copper Corporation's Hayden, Arizona primary copper smelter. The purposes of the test program were:

1. To determine if the smelter's particulate emissions complied with regulations for existing sources
2. To measure quantities of SO_3/H_2SO_4 and SO_2 being emitted to the atmosphere from point sources within the smelter

Tests were conducted at the following point sources:

1. The acid plant tail gas stack
2. The main stack venting emissions from the reverberatory furnace

The main stack was sampled during the period August 5, 1976 to August 11, 1976 and the acid plant tail gas stack was sampled on December 15 and 16, 1976.

This report documents the results obtained and preparations and procedures used by Aerotherm at the Kennecott Smelter. Section 2 presents summaries of all results obtained and some general conclusions. A discussion of the results is found in Section 3. Section 4 and 5 contain descriptions of all preparations and procedures regarding sampling equipment, analytical methods, and sample handling. The Appendices contain supplemental data such as raw data sheets, process operating data, a daily activities summary, calibration data, calculations, and laboratory data.

SECTION 2

RESULTS

Included in this section is a summary of all particulate and gaseous emissions results and process feedrate calculations for the two separate sampling trips. Tests on the Kennecott Copper Smelter reverberatory furnace stack were conducted from 8/5/76 to 8/11/76. Acid plant testing was performed on 12/15/76 and 12/16/76. The allowable particulate emission rates from the acid plant and the main stack are calculated using the formula in the process weight regulation (40 CFR 52.126(b)) and the solid feedrates to the three individual processes (roaster, reverberatory furnace and converters) that produce and vent effluent to the two point sources sampled.

2.1 EMISSION TEST RESULTS

Results of the emission tests are most conveniently displayed in tabular form. Two tables are presented for each point source sampled. They are:

Table 2-1 — Main stack general test data, gas conditions and constituents

Table 2-2 — Main stack particulate and gaseous emissions, isokinetic percentages, and allowable emissions

Table 2-3 — Acid plant tail gas stack general test data, gas conditions and constituents

Table 2-4 — Acid plant tail gas stack particulate and gaseous emissions, isokinetic percentages, and allowable emissions

Also included in this section is a discussion of the procedure for calculating process rates — Subsection 2.2.

TABLE 2-1. MAIN STACK FLUE GAS DATA

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	Run #	Date	% Moisture (B_{wo} x 100)	Volume Gas Sampled (Vm_{std}-scfd)	CO_2 (%)	O_2 (%)	Molecular Wt. Dry Gas (Md-lb/lb mole)	Molecular Wt. Wet Gas (Ms-lb mole)	Velocity (Vs-fps)	Gas Flowrate (Qs-scfh x 10^6)
Hayden Reverb Stack	1	8-5-76	8.3	68.4	4.2	13.5	29.21	28.28	4.6	6.2
	2	8-5-76	7.3	98.4	4.2	13.5	29.21	28.39	7.7	10.3
	3	8-6-76	10.5	48.0	3.7	13.8	29.15	28.98	3.0	3.9
	4	8-9-76	8.5	61.5	4.3	13.6	29.23	28.28	3.8	5.1
	5	8-9-76	8.8	44.6	4.2	13.5	29.22	28.23	3.2	4.2
	6	8-10-76	8.2	49.4	4.3	13.9	29.24	28.32	3.6	4.9
	7	8-11-76	9.6	48.1	4.2	13.6	29.22	28.14	3.0	4.1

TABLE 2-2. MAIN STACK EMISSIONS RESULTS

			Particulate Concentration (gr/acfd)			Particulate Concentration (lb/ft³ x 10⁻⁶)			Particulate Emission Rate (lb/hr)										
Location	Run #	Date	Extrapolated Weight	First Measured Weight	Equilibrium Weight	Extrapolated Weight	First Measured Weight	Equilibrium Weight	Extrapolated Weight	First Measured Weight	Equilibrium Weight	Percent Isokinetic (%)	Allowable Emission Rate (lb/hr)	SO_2 Concentration (ppm)	SO_2 Concentration (lb/ft³ x 10⁻⁴)	SO_2 Emission Rate (lb/hr x 10³)	SO_3/H_2SO_4[b] Concentration (ppm)	SO_3/H_2SO_4[b] Concentration (lb/ft x 10⁻⁶)	SO_3/H_2SO_4[b] Emission Rate (lb/hr)
Hayden Reverb Stack	1	8-5-76	0.040	0.041	0.055	5.7	5.8	7.8	35.2	36.3	48.4	110.1	31.17	[illegible]	7.6	4.7	15	2.4	15.4
	2[a]	8-5-75	0.039	0.039	0.050	5.6	5.6	7.1	57.7	58.2	73.2	94.0	31.17	3507	5.8	5.9	19	3.1	31.9
	3[a]	8-6-76	0.042	0.043	0.064	6.0	6.1	9.1	23.2	23.7	35.2	130.4	31.40	3084	5.1	2.0	0.0	0.0	0.0
	4	8-9-76	0.021	0.021	0.022	3.0	3.0	3.2	15.2	15.3	16.1	109.1	31.48	3265	5.4	2.8	17	2.8	14.2
	5	8-9-76	0.021	0.021	0.022	3.0	3.0	3.1	12.7	12.8	13.2	97.7	31.43	3010	6.3	2.6	16	2.7	11.6
	6[cd]	8-10-76	0.027	0.029	0.032	3.9	4.1	4.6	18.9	19.8	22.2	106.6	30.50	4475	7.4	3.6	18	3.0	14.4
	7[acd]	8-11-76	0.068	0.069	0.074	9.7	9.8	10.5	39.4	40.0	42.8	127.0	20.28	4535	7.5	3.0	7	1.1	4.6

[a] Invalid

[b] As H_2SO_4

[c] Instack filter/outstack filter sampling train

[d] Particulate includes instack filter, outstack filter, probe and nozzle wash

TABLE 2-3. ACID PLANT TAIL GAS STACK GAS DATA

Run #	Date	% Moisture (BWD x 100)	Volume gas Sampled (Vm_{std}-scfd)	SO_2 (%)	O_2 (%)	Mole Fraction Dry Gas (Md-lb/lb mole)	Mole Fraction Wet Gas M_S-lb/lb mole	Velocity (V_S-fps)	Gas Flowrate (Q_S-scfh x 10^6)
1	12-15-77	0.0	50.97	0.2	8.3	28.40	28.40	31.26	4.3
2	12-15-77	0.0	54.77	0.2	8.3	28.40	28.40	32.55	4.6
3	12-16-77	0.0	52.32	0.2	8.3	28.40	28.40	31.59	4.4

TABLE 2-4. ACID PLANT TAIL GAS STACK EMISSIONS RESULTS

Run #	Date	Particulate Concentration (gr/scfd)	Particulate Concentration (lb/ft^3 x 10^{-6})	Particulate Emission Rate (lb/hr)	Percent Isokinetic	Allowable Emission Rate (lb/hr)	SO_2 Concentration (ppm)	SO_2 Concentration (lb/ft^3 x 10^{-4})	SO_2 Emission Rate (lb/hr x 10^2)	SO_3 Concentration (ppm)	SO_3/H_2SO_4[a] Concentration (lb/ft^3 x 10^{-6})	SO_3/H_2SO_4[a] Emission Rate (lb/hr)
1	12-16-76	0.043	6.2	27.0	100.0	66.28	665	1.1	4.6	0.0	0.0	0.0
2	12-16-76	0.023	3.3	15.4	108.7	66.28	726	1.2	5.4	0.0	0.0	0.0
3	12-15-76	0.018	2.6	11.7	95.9	64.84	1270	2.1	8.9	0.0	0.0	0.0

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[a] As H_2SO_4

TABLE 2-5. PROCESS FEED AND ALLOWABLE PARTICULATE EMISSIONS MAIN STACK — REVERBERATORY FURNACE

	August 5	August 6	August 9	August 10	August 11
Tons concentrate to reactor[b]	1029	1102	1079	834	413
Percent sulfur in concentrate[c]	30.9	32.5	29.8	27.3	30.0[a]
Tons to reverb from reactor	870	923	918	720	351
Tons lime[b]	39	41	37	27	16
Tons fettling[b]	39	29	54	81	25
Total tons to reverb	948	993	1009	828	392
Reverb feedrate — tons per hour	39.50	41.38	42.04	34.50	16.33
Allowable emission rate — pounds per hour	31.17	31.40	31.48	30.50	20.28

[a] Actual value not available — 30% is an approximation

[b] Appendix C — Kennecott April 13, 1977 letter

[c] Appendix C entitled "Data for Environmental Control"

TABLE 2-6. PROCESS FEED AND ALLOWABLE PARTICULATE EMISSIONS ACID PLANT — REACTOR AND CONVERTERS

	December 15	December 16
Tons to reactor[a]	1528	1415
Reactor operating hours[b]	22.25	23.50
Reactor feedrate — tons per hour	68.67	60.21
Allowable reactor emission rate — pounds per hour	34.05	33.35
Tons matte to converter[a]	720	738
Tons flux to converter[a]	330	58
Total tons to converter	1050	796
Converter blowing hours[b]	21.58	18.92
Converter feedrate — tons per hour	44.86	42.07
Allowable converter emission rate — pounds per hour	32.23	31.49
Allowable acid plant emission rate — pounds per hour	66.28	64.84

[a] Appendix C — Kennecott, April 13, 1977 letter

[b] Appendix C — Circular charts

2.2 PROCESS FEEDRATE DETERMINATION

In order to determine the allowable particulate emission rates for the acid plant tail gas stack and the main stack, process feedrates for each source had to be determined. The allowable emission rate for the main stack is a function of solids fed to the reverberatory furnace. The allowable emission rate for the acid plant is a function of solids fed to the fluidized bed reactor and the converters. A description of the procedures used to compute these process feedrates follows.

2.2.1 Process Weight and Allowable Emission Rates for the Main Stack

Allowable emissions from the main stack are a function of solids fed to the reverberatory furnace. Since no direct means exists to measure this feedrate, an estimate must be made based on the reactor feed. Briefly, the calculation method suggested by Kennecott states that all the reactor feed goes to the reverberatory furnace as calcine except 50 percent of the feed's sulfur content. This percentage is Kennecott's estimate of the sulfur lost as oxides in the reactor vessel. The sulfur content of the reactor concentrate is analyzed daily and these values for the test days can be found in Appendix C. Lime and felting (for furnace wall protection) are additionally charged to the reverberatory furnace. These values are also found in Table 2-5.

It would be possible to verify the 50-percent loss approximation by analyzing the calcine sulfur content or by doing sulfur oxide emissions tests upstream of the venturi scrubber in the reactor flue. However, this testing is beyond the scope of work for the program.

The formulas used to calculate the allowable particulate emission rates for processes of this type are taken from CFR Title 40 Subsection 52.126. These formulas are:

1. $E = 3.59\ P^{0.62}$ where $P \leq 30$ tons/hour
2. $E = 17.31\ P^{0.16}$ where $P > 30$ tons/hour

where

E = emissions in pounds/hour
P = process weight in tons/hour

Total feedrates to the reverberatory furnace on the test days were all greater than 30 tons/hour except August 11. Therefore Equation (1) was applied to this day's test while Equation (2) was applied to the data from August 5, 6, 9, and 10. Results of these calculations can be found in Table 2-5.

It should be noted that although reactor feedrate data appears in the main stack daily activities section, it has no direct bearing on emissions to the main stack. This is a function of feedrate to the reverberatory furnace. However, reverberatory furnace operation is dependent on feed from the reactor. For this reason — to indicate steady feed to the reverb — this data has been included. Units are in tons for the time period sampled in each port (30 minutes).

2.2.2 Process Weight and Allowable Emission Rates for the Acid Plant

Allowable emissions form the acid plant are a function of solids fed to the reactor and converters. Effluent from these two smelter processes are vented to the acid plant after primary cleaning in the venturi scrubber (reactor off-gases) and the Peabody scrubber (converter off-gases). The reactor feedrate is measured by a weightometer located before the reactor concentrate storage bin. Reactor operating times have been taken from the reactor feedrate circular charts found in Appendix C. Converter total feed weights, which include reverb matte and converter flux, have been provided by Kennecott in their April 13, 1977 letter — also found in Appendix C. Separate emission limits are calculated for each process (roaster and converters). The allowable particulate emission rate from the sulfuric acid plant is determined by summing the two individual process emission rates for the roaster and converter processes.

The formulas used to calculate the allowable particulate emission rates for processes of this type are taken from CFR Title 40 Subsection 52.126. These formulas are:

1. $E = 3.59\ P^{0.62}$ where $P \leq 30$ tons/hour
2. $E = 17.31\ P^{0.16}$ where $P > 30$ tons/hour

where

E = emissions in pounds/hour

P = process weight in tons/hour

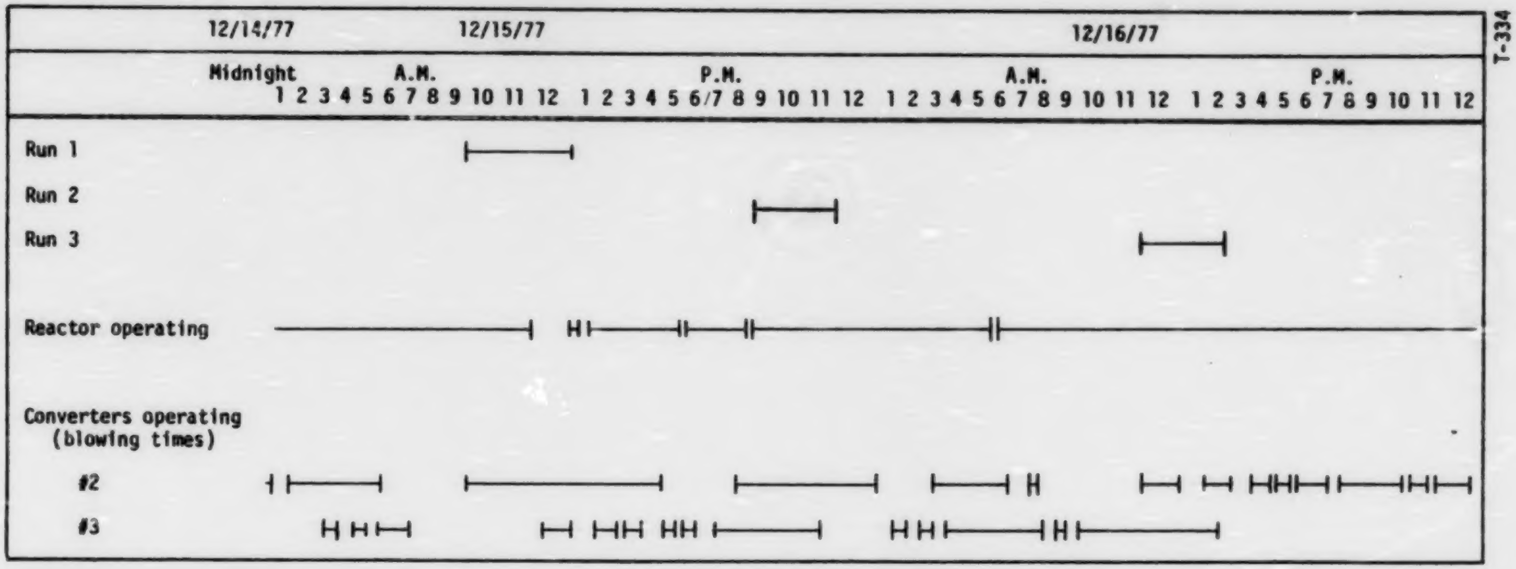
Total process feedrates for December 15 and 16, 1976 are greater than 30 tons/hour therefore Equation (2) is used. Allowable particulate emission rates were then calculated to be 66.28 and 64.84 pounds per hour respectively. The figures used for these calculations can be found in Table 2-6.

There are two weightometers located just before the reactor concentrate storage bin. One of these is not accessible and therefore not calibrated often. The data from this weightometer can be found on circular charts in Appendix C. The figures used in our calculations are from the more accurate weightometer and can be found in Kennecott's April 13, 1977 letter. Reactor operating times were, however, taken from the circular charts.

The hourly converter feedrates were calculated based on examination of the converter blowing charts in Appendix C (Converter number 1 was not operational during the acid plant test series). For a given 24-hour period the total number of hours during which at least one converter was blowing was determined. The total converter feed during the same 24-hour period was then divided by the numbers of hours in which at least one converter was blowing. The resultant figures were the hourly converter feedrates for December 15 and 16, 1976 as shown in Table 2-6.

Table 2-7 presents the sampling schedule and how it coincided with the reactor and converter operating times. The process times have been taken from the circular charts in Appendix C. Time intervals of 10 minutes or less when the process was down have been considered as part of continuous operation.

TABLE 2-7. TEST SCHEDULE



SECTION 3

DISCUSSION OF RESULTS

3.1 MAIN STACK

Table 2-1 summarizes some general test conditions and various flue gas parameters. Table 2-2 summarizes all emissions data and the isokinetic percentages for the main stack tests. Particulate results from tests 2, 3, and 7 have been invalidated for the following reasons:

1. Tests 1, 3, and 7 exceeded the isokinetic sampling guideline required by EPA Method 5 in that they did not fall within the range $90 \leq \text{percent } I \leq 110$. The isokinetic percentages for these tests are 110.1, 130.4 and 127.0 percent respectively. However we believe Test 1 to be acceptable and the results representative. Test 7 has a suspiciously high instack filter weight – indicating the possibility of port scale contamination. Since this is speculation only, it does not constitute a basis for rejection of this test. The high isokinetic percentage, however, is cause for rejection.

2. Test 2 has been discarded because a faulty umbilical cord (kinked pitot tube hoses) produced inaccurate velocity pressure readings yielding results over 100 percent greater than the average velocities of the remaining tests.

Table 3-1 presents a summary of all valid main stack emission rate data. Using data from the three valid filter outstack tests, average particulate emission values have been calculated. They are:

Particulate concentration – 0.027 gr/scfd
Particulate concentration – 3.9×10^{-6} lb/ft^3
Particulate emission rate – 21.0 lb/hour

TABLE 3-1. VALID MAIN STACK EMISSION RATE DATA

Run #	Particulate (lb/hr)	SO_2 (lb/hr x 10^3)	SO_3/H_2SO_4 (lb/hr)
1	35.2	4.7	15.4
2	r	r	r
3	r	2.0	0.0
4	15.2	2.8	14.2
5	12.7	2.6	11.4
6^a	18.9	3.6	14.4
7^a	r	3.0	4.6

r — rejected

a — instack/outstack filter used

Particulate emission values for the valid instack/outstack filter test is:

Particulate concentration — 0.027 gr/scfd

Particulate concentration — 3.9×10^{-6} lb/ft^3

Particulate emission rate — 18.9 lbs/hour

Table 3-2 shows these emission values separated into their filter instack and filter outstack fractions. These figures are not totally accurate because the probe wash and the front half of the outstack filterholder wash was inadvertently included in the nozzle and instack filterholder wash. However we can see that almost 30 percent of the total catch is particulate matter that passed through the instack filter but was caught on the outstack filter and also matter that condensed below stack temperature and above 250°F.

All SO_2 and SO_3/H_2SO_4 emission data is valid with the exception of Test Number 2. Gaseous results are unaffected by nonisokinetic sampling. Although the SO_3/H_2SO_4 results obtained are valid within the constraints of the specified EPA combined Method 5 and 8 procedures, the actual SO_3/H_2SO_4 concentration is probably significantly higher. This is a result of quantities of sulfuric acid mist being caught on the filter and not in the impinger train. This is evidenced by the hygroscopic nature of the filters. The total quantity of SO_3/H_2SO_4 can be determined by sulfate analysis of the filters.

Using data from the six valid gaseous tests, average SO_2 and SO_3/H_2SO_4 emission values have been calculated. They are:

SO_2 concentration (by volume) — 3961 ppm

SO_2 concentration — 6.55×10^{-4} lb/ft^3

SO_2 emission rate — 3.12×10^3 lb/hour

SO_3/H_2SO_4 concentration (by volume) — 12 ppm

SO_3/H_2SO_4 concentration — 2.0×10^{-6} lb/ft^3

SO_3/H_2SO_4 emission rate — 10.0 lb/hour

The results in Table 2-2 for particulate emission rates clearly show the main stack to be within the allowable particulate emission rate based on

TABLE 3-2. COMPARISON OF INSTACK/OUTSTACK SAMPLING TECHNIQUES REVERBERATORY FURNACE MAIN STACK

Particulate Concentration ($lb/ft^3 \times 10^{-6}$) Extrapolated Weight			Particulate Emission Rate (lb/hr) Extrapolated Weight	
Test	Instack[a] Filter	Outstack[b] Filter	Instack[a] Filter	Outstack[b] Filter
6	2.89	1.01	13.99	4.91

[a] Includes instack filter, instack filter holder wash, front half of outstack filter holder wash, nozzle and probe wash residue.

[b] Includes outstack filter only

NOTE: Test No. 7 invalid

the results for the three valid tests. There are no emission regulations for SO_2 or SO_3/H_2SO_4 from primary copper smelters.

A brief statistical analysis on particulate and gaseous emission rates for the three valid tests is presented in Table 3-3.

Particulate concentration and emission rates have been calculated based on "extrapolated weights." Referring to Table 2-2 it can be seen that particulate data has been calculated based on three different filter weights. These weights are a function of the hygroscopic nature of the particulate — laden filters, the relative humidity in the analytical balance room, and the time spent in weighing the filter after removal from the desiccator. Actual weights can be found in Appendix E. The three weights are defined as follows:

Extrapolated weight — filter weight extrapolated to time zero (before any gain in weight due to moisture adsorption)

First measured weight — filter weight measured as soon as possible after removal from the desiccator, usually 15 seconds

Equilibrium weight — filter weight after no more water could be adsorbed from ambient air

The reverberatory furnace electrostatic precipitator (shown schematically in Figure 3-1) was periodically monitored during the main stack test series. Table 3-4 is a summary of the ESP data obtained for the valid stack tests. Data is available for Test 1 — traverse C and tests — traverse D. Four parameters were monitored, they are; primary AC volts, primary AC amps, secondary DC milliamps and spark rate in sparks per minute. Secondary voltage was not metered. This value could be calculated, if desired, although only if a value for transformer efficiency was obtained.

There are a number of items that can be mentioned about the precipitator performance during the testing period. The overall impression of the precipitator was one of a poorly maintained unit. It is desirable to maintain corona voltage high enough to cause some sparking, although not excessive amounts. Approximately 100 sparks per minute is the generally accepted value for the optimum spark rate where the gains from increased voltage are just offset by the losses from sparkover. A number of factors bear on the

TABLE 3-3. STATISTICAL ANALYSIS PARTICULATE AND GASEOUS EMISSIONS — MAIN STACK

	Particulate (lb/hr)[a]	SO_2 (lb/hr x 10^3)[b]	SO_3/H_2SO_4 (lb/hr)[b]
Mean — $\overline{X}$	21.0	3.1	10.0
Standard deviation — σ	12.3	0.9	6.3
90-percent confidence interval — CI	19.9	0.8	5.2
Lower confidence limit — LCL	1.1	2.3	4.8
Upper confidence limit — UCL	40.9	3.9	15.2

[a] Based on valid outstack filter Tests 1, 4 and 5

[b] Based on valid Method 8 Tests 1, 3, 4, 5, 6 and 7

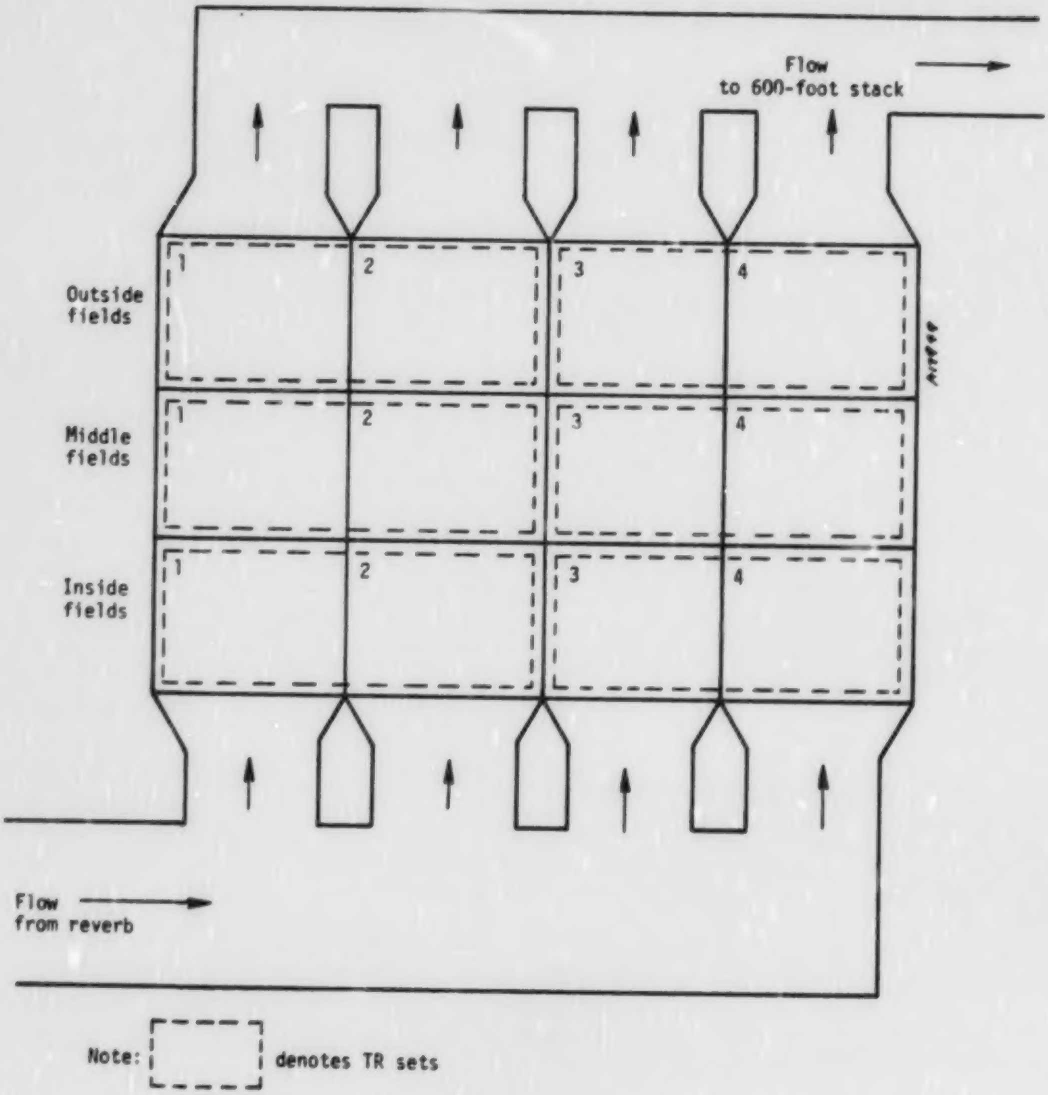

Flow
to 600-foot stack
Outside
fields
Middle
fields
Inside
fields
1
2
3
4
1
2
3
4
1
2
3
4
Flow
from reverb
Note:
denotes TR sets

Figure 3-1. Electrostatic precipitator reverberatory furnace.

TABLE 3-4. REVERBERATORY FURNACE ELECTROSTATIC PRECIPITATOR READINGS FOR THE VALID TESTS

Test-traverse	AC Volts				AC Amps				DC mamps				Sparks/min			
TR set	1-C	4	5-D	6	1-C	4	5-D	6	1-C	4	5-D	6	1-C	4	5-D	6
Outside 1 and 2	310	NA	320	NA	62	NA	62	NA	240	NA	240	NA	0	NA	0	NA
Inside 1 and 2	200	NA	320	NA	28	NA	48	NA	90	NA	160	NA	150	NA	150	NA
Middle 1 and 2	270	NA	260	NA	64	NA	60	NA	240	NA	240	NA	0	NA	100	NA
Middle 3 and 4	280	NA	240	NA	60	NA	NA	NA	240	NA	150	NA	0	NA	0	NA
Inside 3 and 4	270	NA	260	NA	64	NA	46	NA	260	NA	190	NA	0	NA	50	NA
Outside 3 and 4	100	NA	100	NA	62	NA	63	NA	240	NA	140	NA	0	NA	0	NA

NA — not available

spark rate, not the least of which is regular maintenance and fine tuning of the electronics. Kennecott's reverb precipitator typically had zero spark rate in most sections. A possible cause for this is grounded electrodes for which there are numerous causes. TR set inside 1 and 2 typically was at a rate of 150 sparks/minute. This is probably higher than desired resulting in a lowered collection efficiency. High spark rate is usually the result of excessive corona voltage.

It should be stressed that, given the available data on the reverb precipitator, causes for the above mentioned problems are speculative in nature. Only detailed testing and visual internal inspection could determine the actual causes. More information on the Kennecott reverb electrostatic precipitator can be obtained from an upcoming report for EPA by Southern Research Institute.

Tables 3-5 and 3-6 provide additional information on the reverberatory furnace main stack tests. Table 3-5 is a summary of sampling times by test and sample port. Table 3-6 is a summary of visual observations of the color of samples.

3.2 ACID PLANT

Table 2-3 summarizes some general test conditions and various flue gas parameters. Table 2-4 summarizes all emissions data and the isokinetic percentages for the acid plant particulate compliance and sulfur oxides tests. As indicated by the data, all three tests conducted on the acid plant effluent were within the ±10-percent isokinetic sampling guideline required by EPA Method 5. As a result, no inaccuracies in emission data were introduced by a failure to meet these guidelines.

Using data from the three valid tests, average emission values have been calculated. They are:

Average emissions – acid plant

Particulate concentration – 0.028 gr/scfd

Particulate concentration – 4.0×10^{-6} lb/ft^3

Particulate emission rate – 18.0 lb/hour

TABLE 3-5. SUMMARY OF SAMPLING TIMES — REVERBERATORY FURNACE MAIN STACK

Test	Date	Port	Time Start	 Finish
1	8-5-76	B	0951	1021
		A	1055	1125
		D	1158	1128
		C	1301	1331
2	8-5-76	C	1636	1706
		D	1740	1810
		A	1839	1909
		B	1951	2021
3	8-6-76	C	1147	1217
		D	1245	1315
		A	1402	1432
		B	1510	1540
4	8-9-76	C	1057	1127
		D	1157	1227
		A	1240	1310
		B	1322	1352
5	8-9-76	C	1540	1610
		D	1635	1705
		A	1744	1814
		B	1835	1905
6	8-10-76	C	1325	1355
		D	1425	1455
		A	1544	1613
		B	1640	1710
7	8-11-76	C	1045	1115
		D	1145	1215
		A	1302	1332
		B	1400	1430

TABLE 3-6. SUMMARY OF SAMPLE COLOR OBSERVATIONS REVERBERATORY FURNACE MAIN STACK

Test		142-mm Filter	IPA impingers		H_2O_2 impingers	50-mm Filter
			# 1	# 2		
1	1st train	dark green	pale brown	clear	clear	white
	2nd train	NA	pale yellow	pale milky white	clear	white
2	1st train	NA	pale yellow	pale yellow	clear	light yellow
	2nd train	NA	pale milky white	pale yellow	clear	white
3		brown	murky	clear	clear	white
4	1st train	NA	slight colored	clear	clear	white
	2nd train	NA	dirty yellow	clear	clear	white
5	1st train	NA	clear	grey	clear	dark grey
	2nd train	NA	clear	clear	clear	white
6	1st train	NA	slightly milky	clear	clear	white
	2nd train	NA	light brown	clear	clear	white
7	1st train	NA	light white	clear	clear	white
	2nd train	NA	white	clear	clear	white

NOTE: NA — not available

SO_2 concentration (by volume) — 887 ppm

SO_2 concentration — 1.5 x 10^{-4} lb/ft^3

SO_2 emission rate — 630 lb/hour

SO_3/H_2SO_4 — 0

The results in Table 2-4 for particulate emissions rates clearly show the acid plant tail gas stack to be within the allowable particulate emission rate of approximately 65 pounds/hour. There are no emissions regulations for SO_2 and SO_3/H_2SO_4 from the acid plant.

A brief statistical analysis on particulate and SO_2 emission rates for the three tests is presented in Table 3-7. A sample statistical calculation for acid plant particulate emission rate is included in Appendix B.

A breakdown of particulate weights can be found in Table 3-8. Included are residue weights for the front half acetone wash and for the filter.

The only anomaly in the acid plant emissions results is the SO_2 emission concentration during Test No. 3. The average value in Test No. 1 and No. 2 is approximately 700 ppm while Test No. 3 increased to 1270 ppm. There are two possible explanations for this. The first is the brief upset during Test No. 3 of one of the acid plant blowers. Although we were able to shut down the test very soon after the upset occurred, there probably were a few minutes overlap between the testing time and the upset. What seems to be a more likely cause for the high tail gas SO_2 is the low and very erratic SO_2 gas strength received at the acid plant. Referring to the charts in Appendix C, the inlet SO_2 concentration for Tests No. 1 and 2 held relatively constant at 6 and 8 percent while in Test No. 3 this value varied greatly between 1 and 6 percent. We suspect that drastic changes in SO_2 feed strength is a cause of erratic acid production and variable and high SO_2 tail gas concentration.

Test No. 3 aside, the acid plant operation appeared to be representative of normal operation, as was the reactor and converter operation.

TABLE 3-7. STATISTICAL ANALYSIS PARTICULATE AND GASEOUS EMISSIONS — ACID PLANT

	Particulate (lb/hr)	SO_2 (lb/hr x 10^2)
Mean — $\overline{X}$	18.0	6.3
Standard deviation — σ	8.1	2.3
90-percent interval — CI	13.0	3.7
Lower confidence limit — LCL	5.0	2.6
Upper confidence limit — UCL	31.0	10.0

TABLE 3-8. PARTICULATE WEIGHTS (MILLIGRAMS) FOR METHOD 5 TESTS AT THE ACID PLANT TAIL GAS STACK

	Test #1	Test #2	Test #3
Front half washings*	86.9	38.8	60.4
Filter	56.8	23.7	22.1
Total	143.7	62.5	82.5

[a] Includes nozzle, probe and front half of filterholder

SECTION 4

EQUIPMENT DESCRIPTION AND PREPARATION

4.1 METHODS 5 and 8 TRAIN

This section describes the major components of the Methods 5 and 8 train and the procedures used to prepare the components for calibration and testing.

4.1.1 Nozzles

All sampling nozzles were constructed of 316 stainless steel and had a sharpened edge. They were prepared for field use by thorough cleaning and grinding any damaged edges to restore the specified diameter.

4.1.2 Probes

The sampling probe used on the acid plant was a 5-foot heated 316 stainless steel probe with a replaceable pyrex glass liner. The sampling probe used on the reverberatory furnace stack was a 10-foot heated 316 stainless steel probe with a replaceable 316 stainless steel liner. In addition, it has provisions for an instack filter holder (Gelman type — 47 mm). Figure 4-1 shows the instack filter holder assembly. The front end of both probes are equipped with a thermocouple and an S-type pitot tube. The probes were prepared by thoroughly cleaning and inspecting the liners for cracks, inspecting the pitot tube tips for damage, and electrically checking the heaters and thermocouples.

4.1.3 Filter/Cyclone Ovens

Both ovens are equipped with an electric heating element and a thermocouple. The cyclone oven has a circulation fan and a rack for storage of a filter housing. The ovens were prepared by checking out all electrical components (heaters, thermocouples, fans). Heater controllers were checked for their ability to maintain oven and probe temperatures of 250°F.

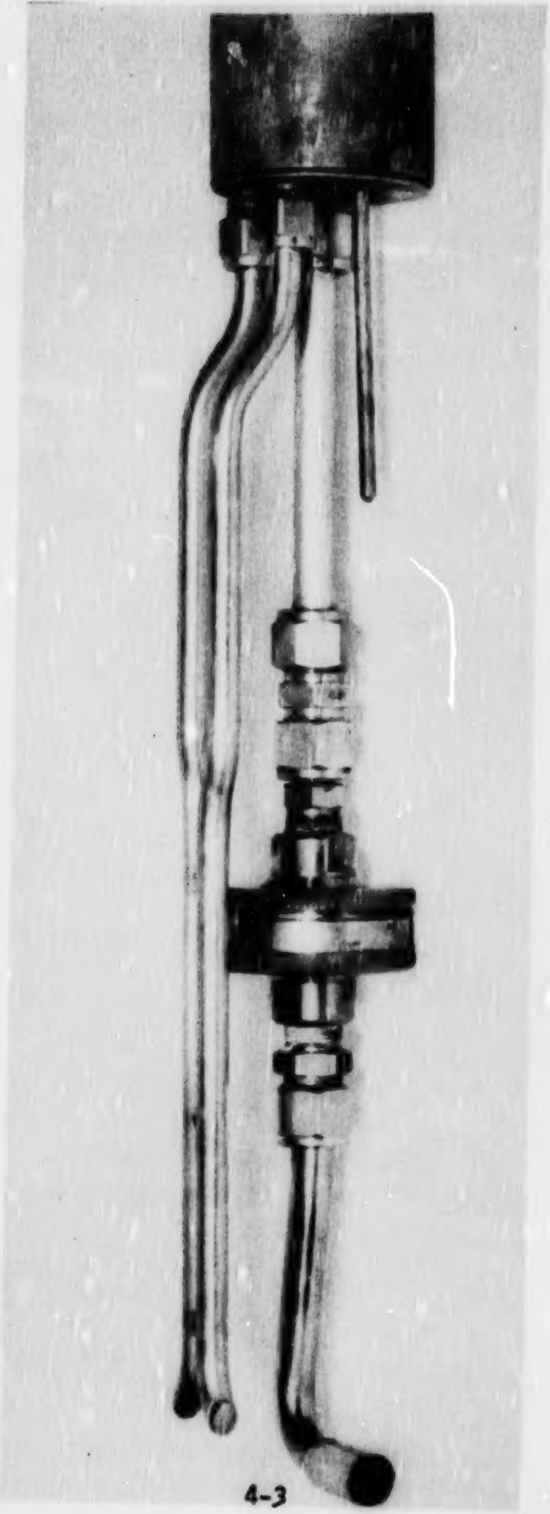


Figure 4-1. In-stack filter holder assembly.

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4.1.4 Umbilicals

A common umbilical line is used to make all electrical and pitot tube connections between the control module and the oven and probe. It was tested in the system before use.

4.1.5 Pumps

A 10-cfm carbon vane vacuum pump is used in each system. The pumps were leak checked at maximum vacuum before use.

4.1.6 Control Modules

The control module contains all of the instrumentation necessary to measure the temperatures and flowrates in the sampling system. It it also equipped with closed-loop temperature controllers for precise regulation of the probe and oven heaters. All gauges and controls were checked for proper operation before testing.

4.1.7 Impinger Train

A 1-cfm Greenburg-Smith glass impinger train was used for the EPA Methods 5 and 8 sampling. The first two impingers were filled with 80-percent isopropanol to absorb sulfuric acid mist. A glass fiber filter was placed between the second and third impingers to capture any entrained mist. The third and fourth impingers contained 3-percent hydrogen peroxide to absorb sulfur dioxide. The fifth impinger was dry and the sixth impinger contained silica gel to remove any remaining moisture. A thermocouple in the last impinger was used to monitor outlet gas temperature.

4.1.8 Glass Fiber Filters

All glass fiber filters to be used for the stack test were obtained from Schleicher and Schuell and fully meet EPA Method 5 specifications. The filters were placed in an oven at 300°F for 3 hours, then placed into individual plastic petri dishes and put in a desiccator for conditioning over silica gel for at least 24 hours. The filters were then taken to the balance room and weighed to the nearest 0.01 milligram on a Mettler Model H20 analytical balance. After weighing, each filter was returned to the plastic pertri dish, which was sealed with masking tape and labeled with the filter number and tare weight. This information was also recorded in the filter record book.

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4.2 CALIBRATION PROCEDURES

After the sampling equipment was prepared and inspected, certain components of the sampling trains were calibrated. The procedures used are presented in this section.

4.2.1 Nozzles

Nozzle size selection is a field operation and therefore so is nozzle calibration. After the proper nozzles were selected, they were measured to the nearest thousandth inch on three diameters. The average value was used for calculation purposes.

4.2.2 Thermocouples and Digital Temperature Indicators

All thermocouples are connected to a digital temperature indicator on the control module. The indicator has a specified accuracy of ±4°F over a range from 0°F to 1500°F.

Each of the six thermocouples was calibrated in two ways. They are:

1. Comparison of the thermocouple readout to a 32°F ice bath
2. Comparison of each thermocouple to a Fluke Model 2100A digital thermometer calibrated twice a year against an NBS traceable standard

Comparison readings were made in a 250°F oven.

4.2.3 Dry Gas Meter and Orifice Meter

A Rockwell Model 415 gas meter (illustrated in Figure 4-2) is used to simultaneously calibrate the dry gas meter and orifice meter in each control module. This calibration standard is the same type of meter that is used in the control module of each sampling train. The accuracy of the Rockwell meter has been verified against a National Bureau of Standards traceable bell prover maintained by the Pacific Gas & Electric Company. In addition, the Rockwell meter never leaves Aerotherm's Source Evaluation Laboratory.

Calibration is accomplished by passing a known volume of gas through the test and calibration meter at certain flowrates. Flowrates are indicated by the orifice meter. A number of flowrates are tested in the useful

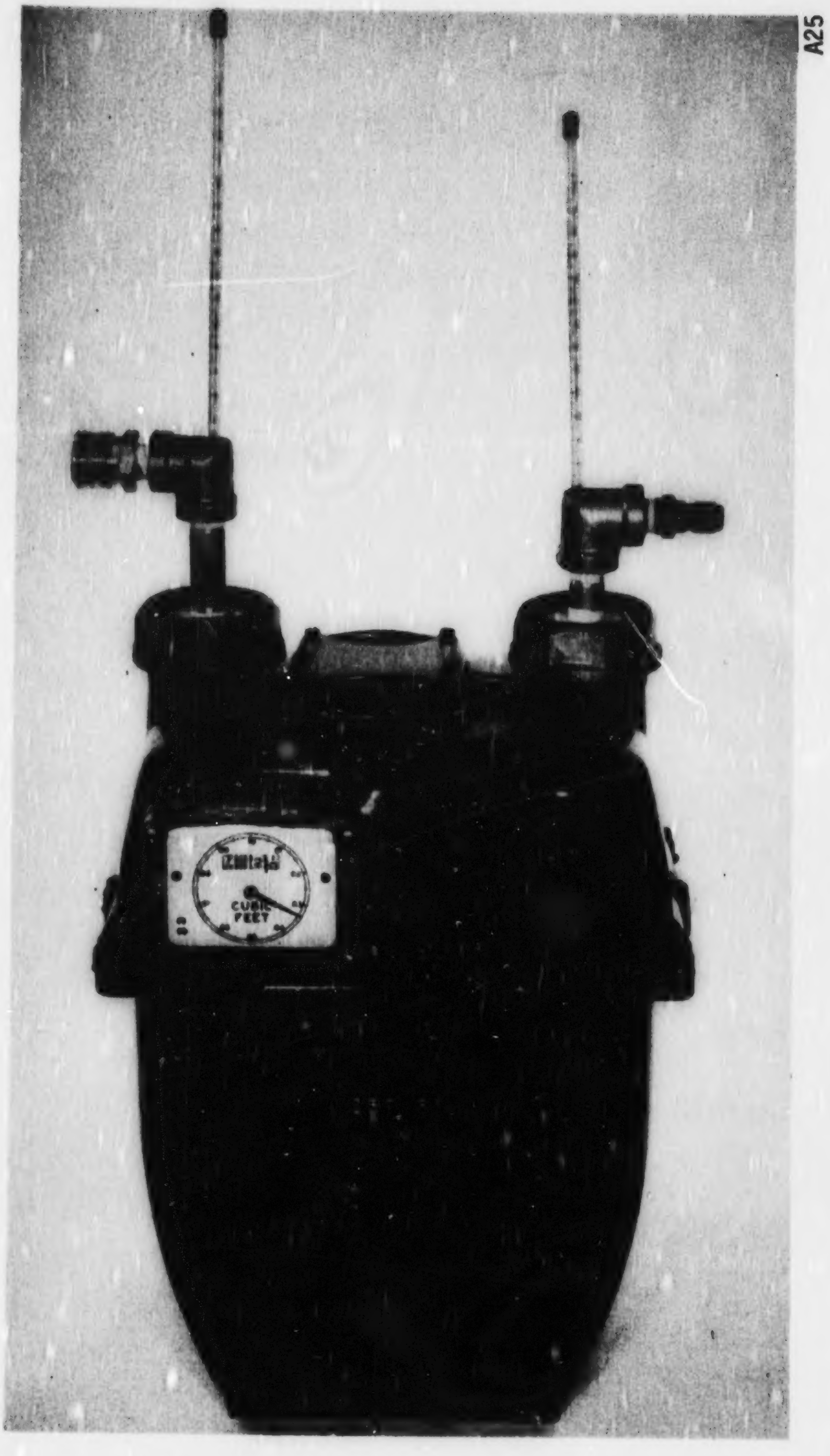
A25
CUBIC
FEET

Figure 4-2. Rockwell model 415 gas meter calibration standard.

range of the orifice meter. The appropriate temperature, pressure, and volume data is recorded and used to calculate calibration constants for the dry gas meter and orifice meter in each control module.

At the completion of a calibration run, the final dry gas meter readings and the final inlet and outlet dry gas meter temperatures were recorded. The same procedure was reported at four different flowrates to calibrate the orifice meter over its entire useful range. The data from these calibrations were then used to calculate the calibration constants for the dry gas meter and the orifice meter in each control module.

The formula used to calculate the calibration constant for the dry gas meter is as follows:

$$\alpha = \frac{\left(V_d P_{bar} + \frac{\Delta H_o}{13.6}\right)\left(\frac{T_{pi} + T_{po}}{2} + 460\right)}{\left(V_p P_{bar} \frac{\bar{T}_{di} + T_{do}}{2} + 460\right)}$$

where

α = calibration constant for dry gas meter in the control module

V_d = total volume of gas passing through the dry gas meter in the control module, ft^3

V_p = total volume of gas passing through the calibration standard meter, ft^3

P_b = barometric pressure, inches Hg

ΔH_o = pressure drop across the orifice meter in the control module, inches H_2O

13.6 = conversion factor, inches H_2O/inches Hg

T_{di} = inlet temperature of dry gas meter in the control module, °F

T_{do} = outlet temperature of dry gas meter in the control module, °F

T_{pi} = inlet temperature of calibration standard meter, °F

T_{po} = outlet temperature of calibration standard meter, °F

460 = conversion factor, °F to °R

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The meter readings obtained during the field tests were divided by α to obtain the true volume.

$$K_o = \frac{V_p}{t\left(\frac{T_{do}\ \Delta H_o}{P_{bar}\ M_m}\right)^{1/2}}$$

where

K_o = calibration constant for the orifice meter in the control module

V_p = total volume of gas passing through the calibration standard meter, ft^3

T_{do} = outlet temperature of dry gas meter in the control module, °F

t = calibration time, minutes

ΔH_o = pressure drop across the orifice meter in the control module, inches H_2O

P_{bar} = barometric pressure, inches Hg

M_m = molecular weight of the air, 28.96 lb/lb-mole

An average calibration constant was determined for the dry gas meter and orifice meter in each control module by averaging the individual test results. The calibration data for each control module used during the field tests are presented in Appendix D.

4.2.4 S-Type Pitot Tube

All S-type pitot tubes are calibrated in the Aerotherm wind tunnel illustrated in Figure 4-3. A united sensor hemispherical nose standard pitot tube (Figure 4-4), with a 0.99 coefficient, is the calibration standard. Velocity pressure from the S-type pitot tube and standard pitot tube is read on a Dwyer inclined manometer shown in Figure 4-5. The S-type pitot tube is calibrated in the same configuration that it will be in during actual use — that is, mounted on the probe with a nozzle and thermocouple. Comparison readings are made over a wide range of velocities with both legs of the pitot tube alternately measuring impact pressure.

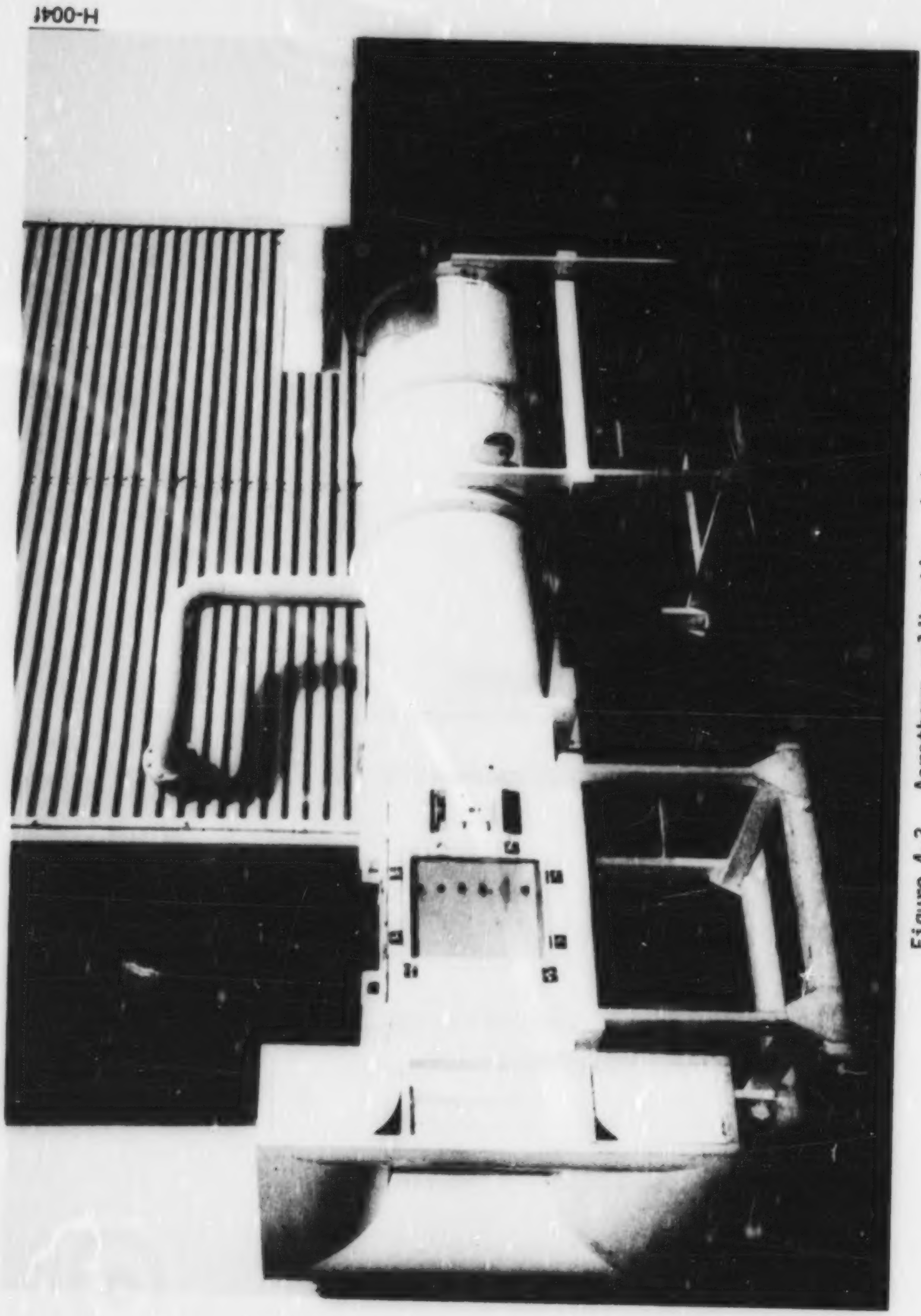

Figure 4-3. Aerotherm calibration wind tunnel.

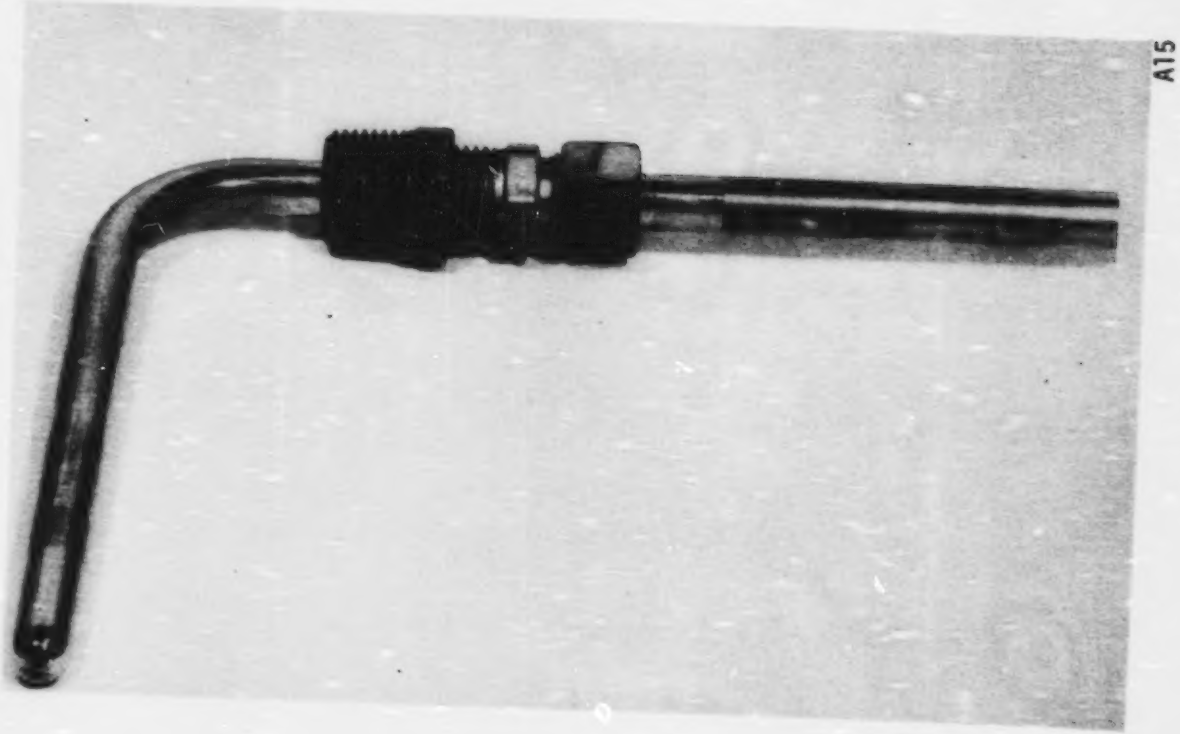

Figure 4-4. United Sensor hemispherical nose standard probe tube.

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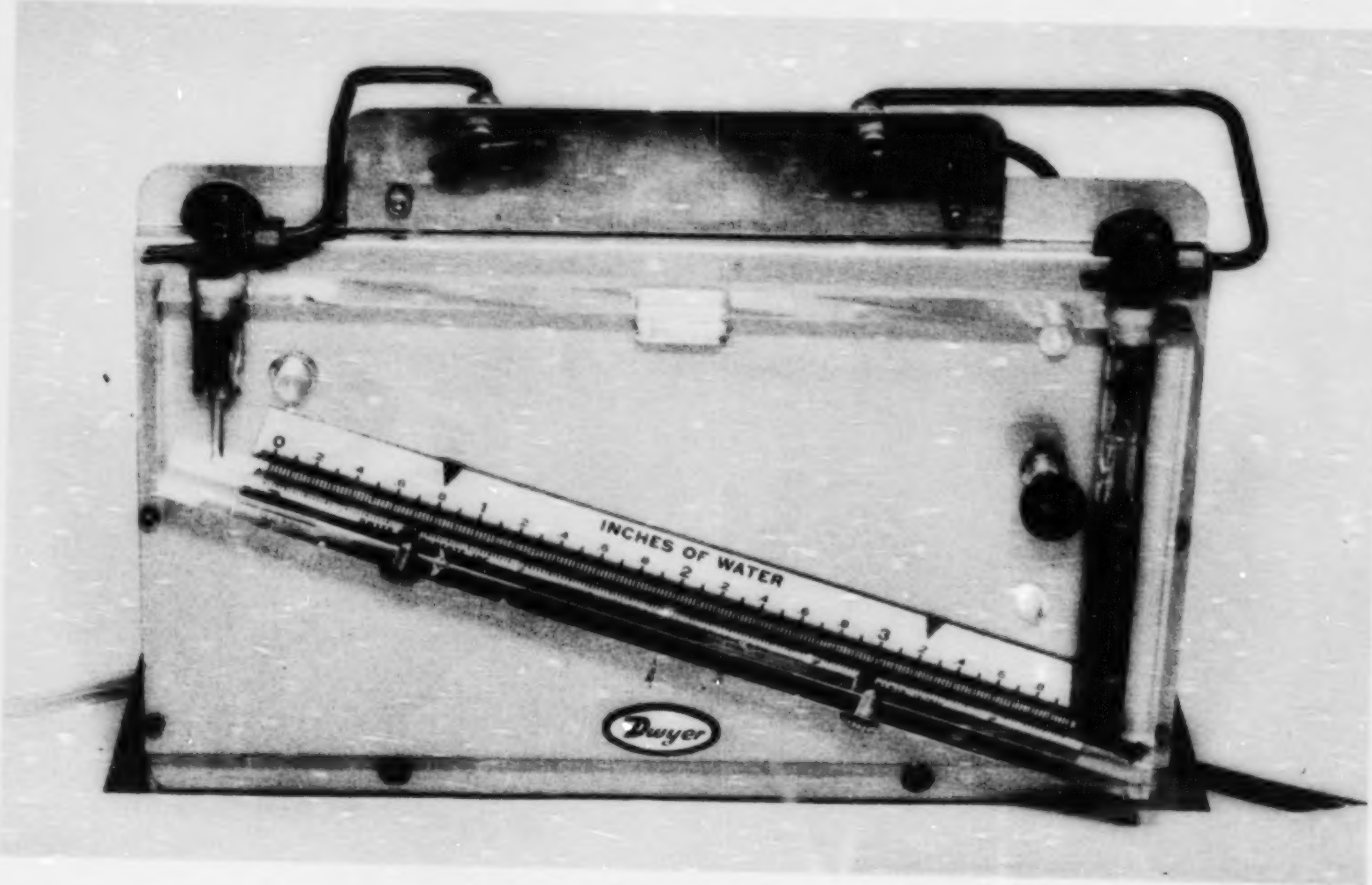
INCHES OF WATER
Dwyer

Figure 4-5. Dwyer inclined manometer.

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The formula used to calculate the coefficient for the S-type pitot tube for each sampling probe is as follows:

$$Cp_{S\text{-}type} = 0.99 \left(\frac{\Delta P_{std}}{\Delta P_{S\text{-}type}}\right)^{1/2}$$

where

$Cp_{S\text{-}type}$ = coefficient of the S-type pitot tube

ΔP_{std} = velocity pressure measured by the standard pitot tube, inches H_2O

$\Delta P_{S\text{-}type}$ = velocity pressure measured by the S-type pitot tube, inches H_2O

0.99 = coefficient of the standard pitot tube

The average coefficients for the upper and lower legs of the S-type tube were calculated by averaging the individual coefficients of each calibration run. These average values were recorded on the calibration data sheet. Tables that summarize all the calibration data for the S-type pitot and sampling probes that were used during the field test program can be found in Appendix D.

4.2.5 Differential Pressure Gauges

Differential pressure gauges were connected to an orifice flow meter and compared against the Dwyer inclined manometer discussed in Section 4.2.4. The calibration procedure was repeated at several different flowrates. If readings differed between the gauges and manometer, the gauge was adjusted and the calibration was repeated until the readings agreed.

A Validyne differential pressure transducer was used in place of the conventional pressure gauges on the reverberatory furnace main stack. Conventional gauges are unable to sense velocities of approximately 5 fps. The Validyne transducer was calibrated against an NBS traceable inclined manometer. Calibration data is located in Appendix D.

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4.2.6 Isopropanol

It has been found that errors in acid mist values can be caused by peroxide impurities in the isopropanol impinger solutions. To prevent this error, Aerotherm analyzed the isopropyl alcohol prior to shipping it into the field, in accordance with an EPA method, to determine if it contained any peroxides. Ten mls of isopropyl alcohol were shaken with 10 mls of freshly prepared 10-percent potassium iodide solution. A blank was prepared by similarly treating 10 mls of distilled water, and the absorbance of each solution was read at 362 nanometers. The absorbance of the solution was less than 0.1, demonstrating that the alcohol was uncontaminated by peroxides. Since the same isopropanol source was used for both test series, this quality control check was run only before the first test series.

4.2.7 Mettler Analytical Balance

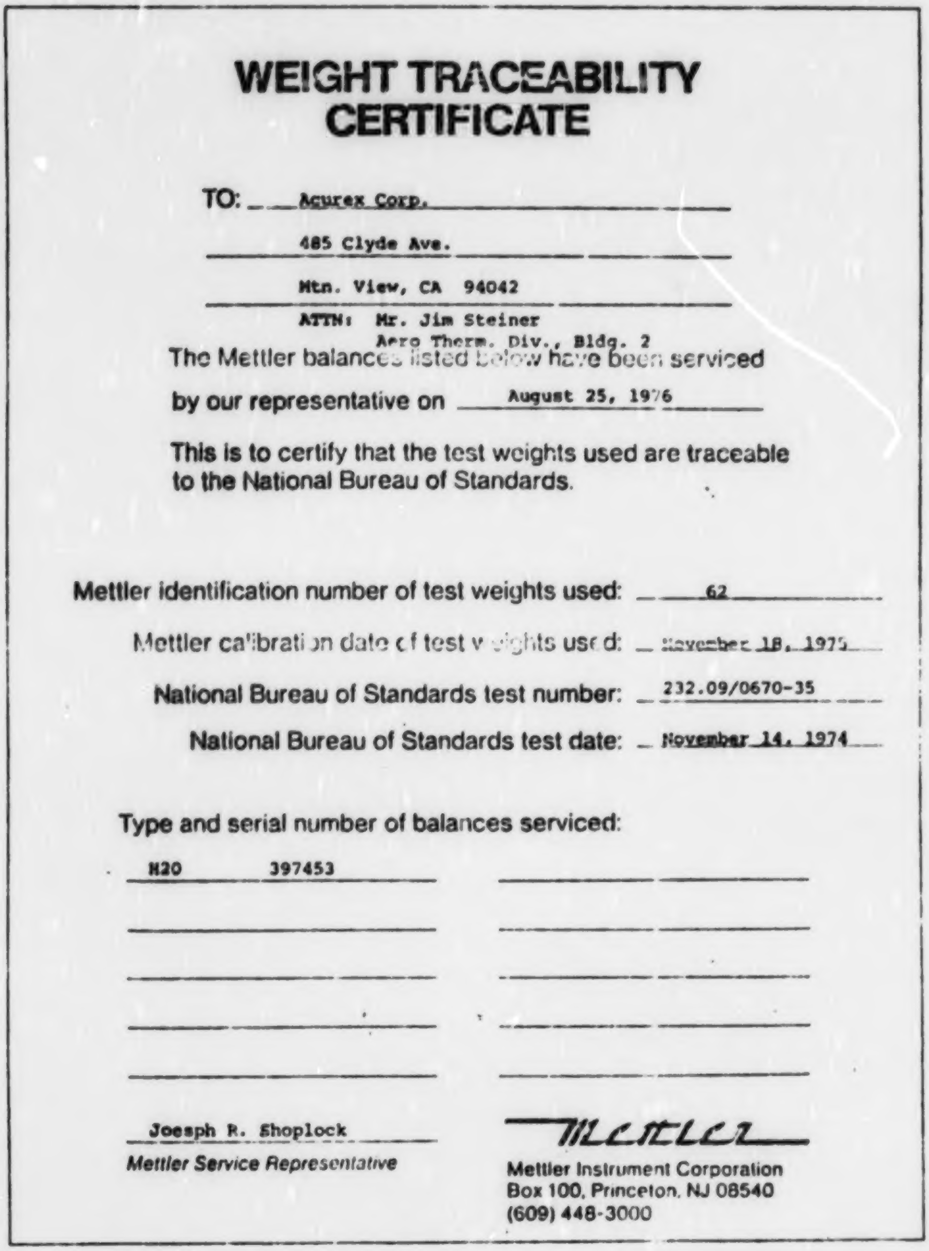
A Mettler Model H20 balance, which can be read to 0.01 mg, was used to weigh the glass fiber filters and the chemicals used to prepare solutions. This balance is checked twice a year by the Mettler Instrument Corporation against National Bureau of Standard weights to insure its accuracy. Figure 4-6 illustrates the certificate issued by Mettler for the most recent calibration on the balance.

4.3 MOISTURE TRAIN

A separate train is necessary to measure moisture when Methods 5 and 8 are combined in a common train because the evaporation of isopropanol in the Method 8 impinger train interferes with a volumetric measurement of water. A standard heated probe with a pitot tube was placed at a single point in the stack. The gas was drawn through two water-fitted impingers, a dry impinger and an impinger containing silica gel. A standard control module and pump were used for monitoring and controlling flow. The sampling rate was varied in proportion to changes in the stack gas velocity.

4.4 GAS SAMPLING TRAIN

A gas sample was drawn from a tee in the first impinger inlet of the moisture train and fed to a 30-liter Tedlar bag. A separate pump, flow



WEIGHT TRACEABILITY CERTIFICATE

TO: Acurex Corp.
485 Clyde Ave.
Mtn. View, CA 94042
ATTN: Mr. Jim Steiner
Aero Therm. Div., Bldg. 2

The Mettler balances listed below have been serviced by our representative on August 25, 1976

This is to certify that the test weights used are traceable to the National Bureau of Standards.

Mettler identification number of test weights used: 62

Mettler calibration date of test weights used: November 18, 1975

National Bureau of Standards test number: 232.09/0670-35

National Bureau of Standards test date: November 14, 1974

Type and serial number of balances serviced:

H20 397453

Joesph R. Shoplock
Mettler Service Representative

Mettler
Mettler Instrument Corporation
Box 100, Princeton, NJ 08540
(609) 448-3000

Figure 4-6. Weight traceability certificate.

meter, and valve were used in this train. The flowrate of gas into the bag was also varied in proportion to changes in the stack gas velocity. The gas collected in the bag was later sampled with an Orsat analyzer. Figure 4-7 illustrates the combined EPA Method 3 and 4 sampling train.

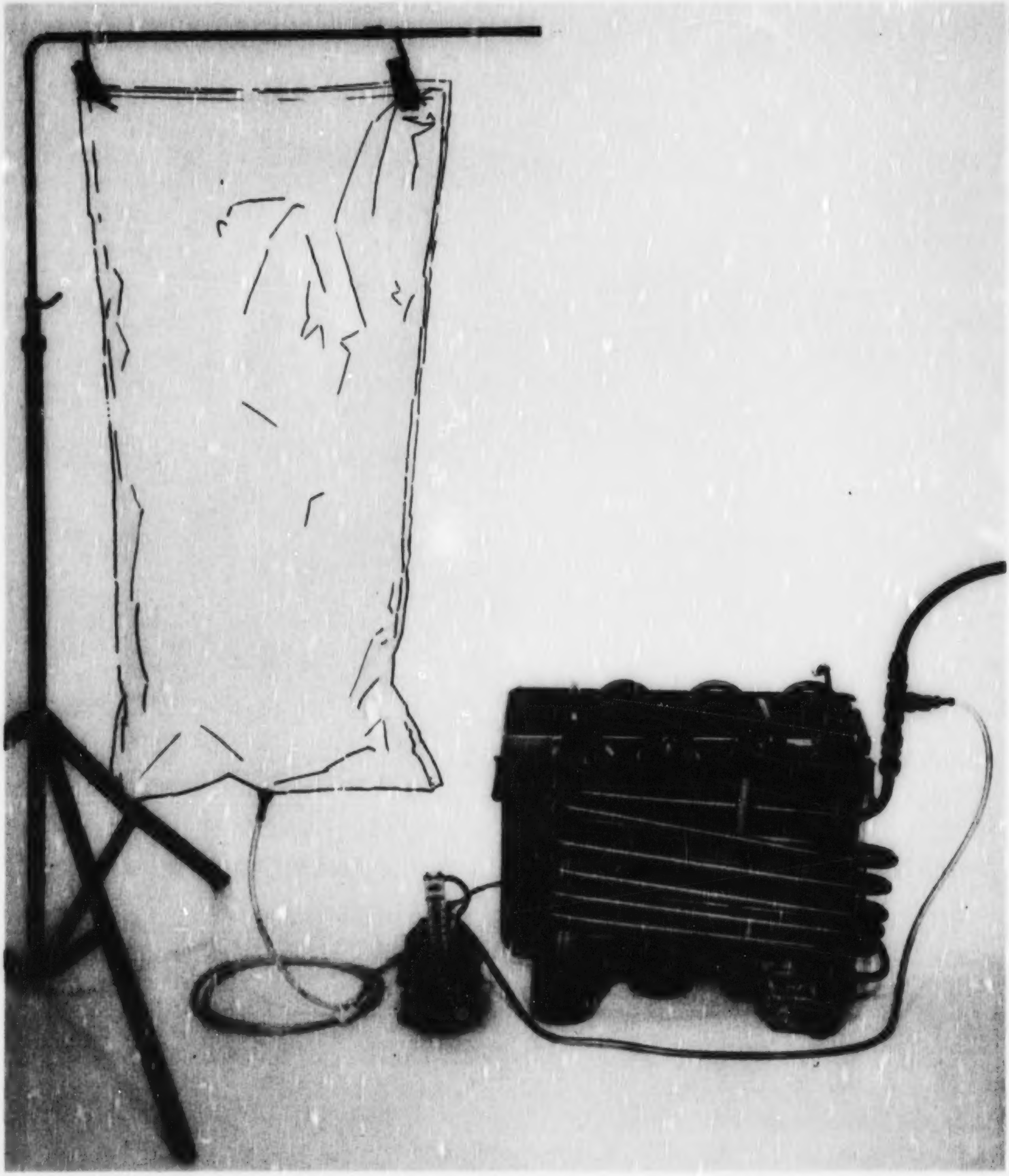


Figure 4-7. Combined EPA Method 3 and 4 sampling train.

SECTION 5

PROCEDURES

This section describes the procedures used for sampling, sample recovery, and sample analysis at both test locations.

5.1 SAMPLING

5.1.1 Preliminary Measurements and Calculations

The test crew at each location — the acid plant and reverberatory furnace — made preliminary stack measurements and obtained the following information.

	Acid Plant	Reverb
Inside diameter (feet)	8.0	28.36
Nearest upstream disturbance (dia.)	1.6	6
Nearest downstream disturbance (dia.)	1.1	>2

The number of sample points and their location were determined from this information using EPA Method 1 and are shown in Table 5-1. The crew at the acid plant sampled 24 points in each of two ports, 90 degrees apart. The main stack crew sampled six points in each of four ports, 90 degrees apart.

Figure 5-1 presents diagrams of the three major processes in the smelter which generate gaseous and particulate pollutants. Off-gases from the roaster and converters are vented to the acid plant after treatment by various combinations of cyclones, scrubbers and electrostatic precipitators. The December 15 and 16 tests were conducted on the acid plant tail gas stack. Off-gases from the reverberatory furnace pass through a ballon flue and on electrostatic precipitator before being emitted via the main stack — where the August tests were conducted.

TABLE 5-1. SAMPLE POINT DISTANCES FROM STACK WALL (INCHES)

Point Number	Tail Gas Stack (2 ports, 48 points total)	Main Stack (4 ports, 24 points total)
1	1.0	7.1
2	3.1	22.8
3	5.3	40.2
4	7.6	60.2
5	10.1	85.1
6	12.7	120.8[a]
7	15.5	
8	18.6	
9	22.1	
10	26.1	
11	31.0	
12	38.2	
13	57.8	
14	65.0	
15	69.9	
16	73.9	
17	77.4	
18	80.5	
19	83.3	
20	85.9	
21	88.4	
22	90.7	
23	92.9	
24	95.0	

[a] This point could not be reached, so Point No. 5 was sampled twice (see Daily Activities Report).

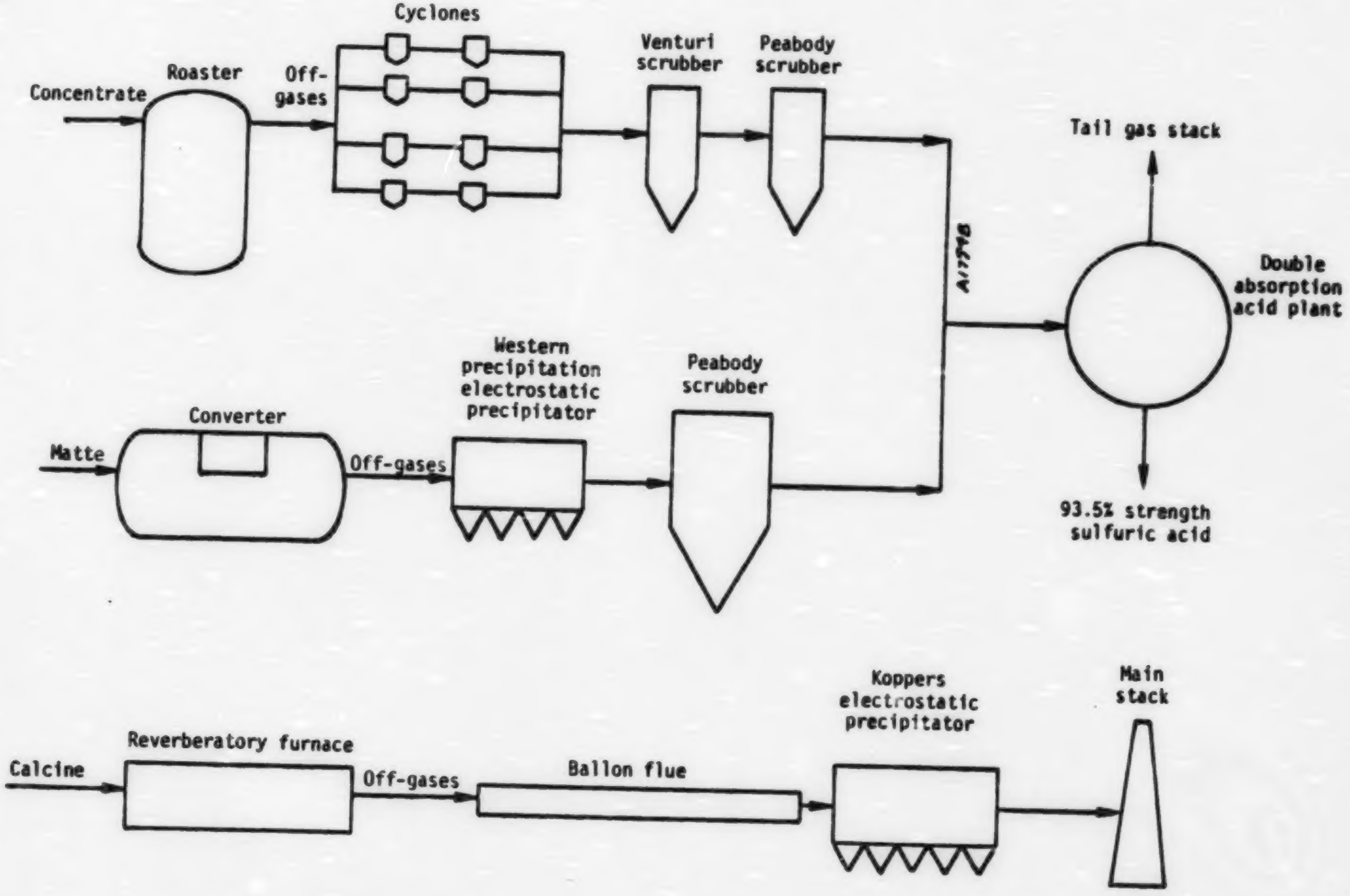

Cyclones
Concentrate
Roaster
Off-gases
Venturi scrubber
Peabody scrubber
Tail gas stack
Double absorption acid plant
A11778
Western precipitation electrostatic precipitator
Peabody scrubber
Converter
Matte
Off-gases
93.5% strength sulfuric acid
Koppers electrostatic precipitator
Main stack
Calcine
Reverberatory furnace
Off-gases
Ballon flue

Figure 5-1. Process diagrams.

To further clarify the sampling locations, the following diagrams and photographs have been included:

Figure 5-2 Sampling location — and plant tail gas stack

Figure 5-3 Sampling location — reverberatory furnace main stack

Figure 5-4 Main stacks ports A and B

Figure 5-5 Main stack ports C and D

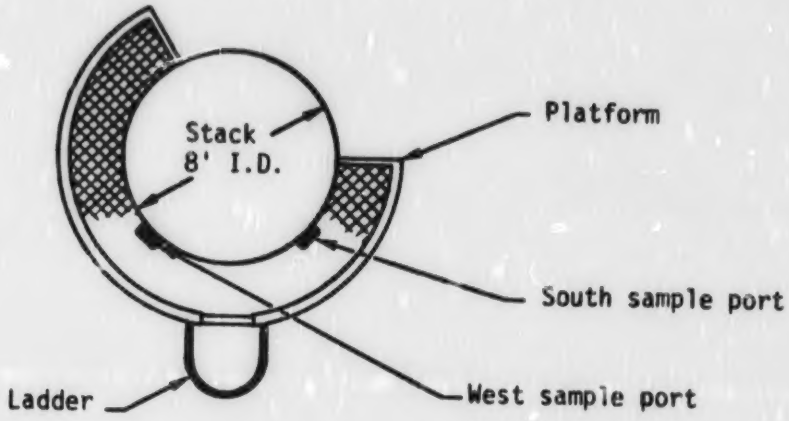
As shown in Figure 5-1, point No. 6 on the reverberatory furnace stack (main stack) could not be sampled. This was due to restrictions imposed by the sample probe support system. It was decided to sample point No. 5 twice to compensate. A velocity profile of the reverberatory furnace tests 3, 4 and 5 shows that this had a negligible effect on the test outcome. It can be seen in Figure 5-6 that from the trend of the velocity profile for points 1 through 5, the actual velocity for point No. 6 would, in all probability, be very close to that of point No. 5. If there is any effect on the test outcome, it would show up as a very slight underestimate of gas flowrate and mass emission rate.

A preliminary traverse was made to determine the velocity and temperature at the sample points (EPA Method 2), the stack gas molecular weight (EPA Method 3), and the moisture content of the gas (EPA Method 4). These measurements were made simultaneously with the moisture and gas sampling trains.

A series of calculations was performed for each test location to determine the following:

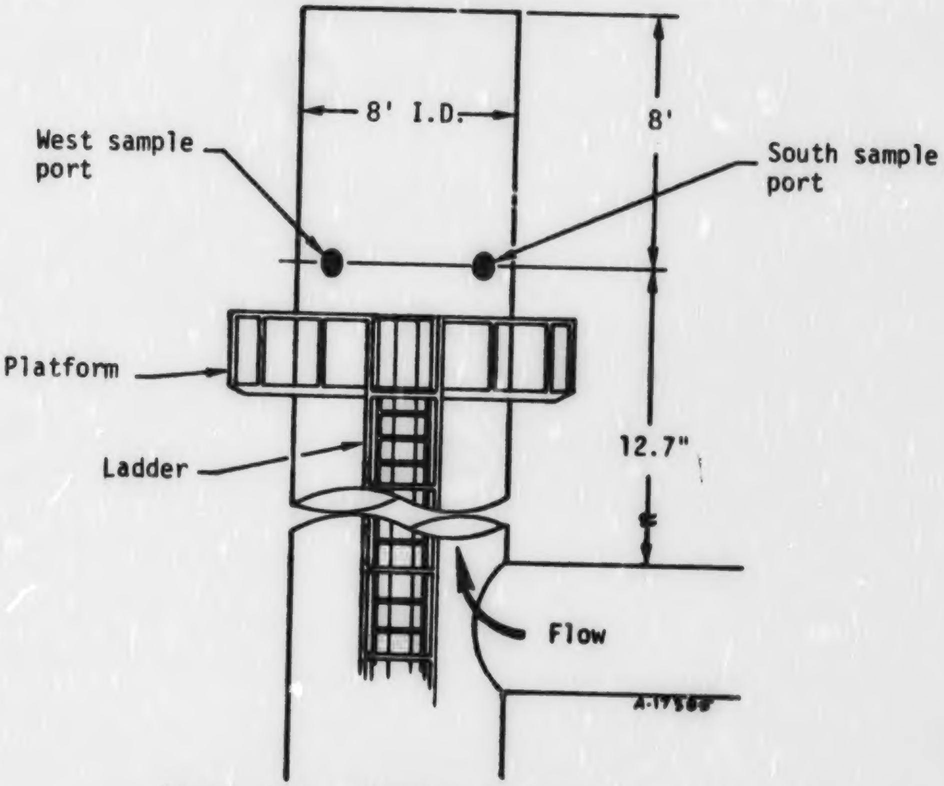
- Dry molecular weight (M_d) of the stack gases using Equation (3-2) of Appendix A to 40 CFR Part 60
- Wet molecular weight (M_s) of the stack gases using $M_s = M_d (1 - B_{wo}) + 18 (B_{wo})$
- Moisture content of the stack gases (B_{wo}) using Equations (4-1), (4-2), and (4-3) of Appendix A to 40 CFR Part 60

These terms (M_d, M_s, B_{wo}) are assumed to remain constant during a given test run. Although variations in M_d and M_s have an insignificant effect on isokinetic sampling, variations in B_{wo} will have a significant effect.



Plan View

Stack
8' I.D.
Platform
South sample port
Ladder
West sample port



Elevation View

8' I.D.
8'
West sample port
South sample port
Platform
12.7"
Ladder
Flow
A-17568

Figure 5-2. Sampling location acid plant tail gas stack.

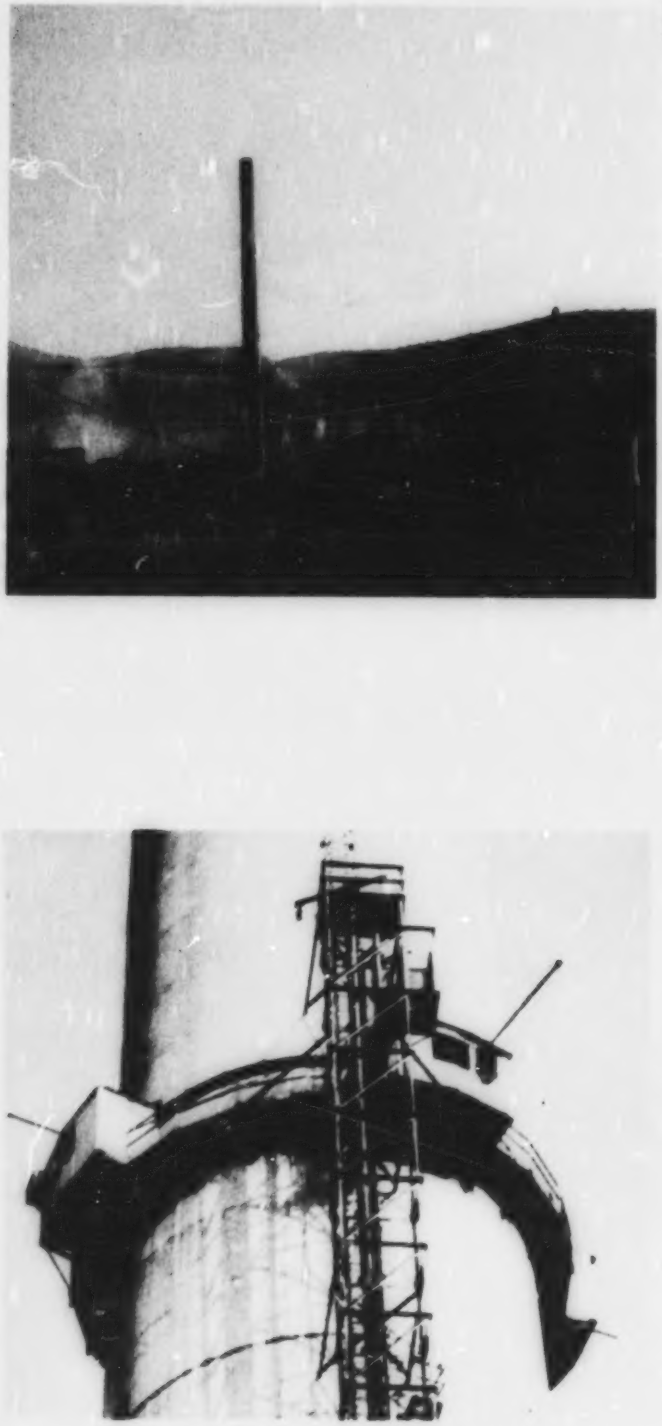


Figure 5-3. Sampling location — reverberatory furnace main stack.

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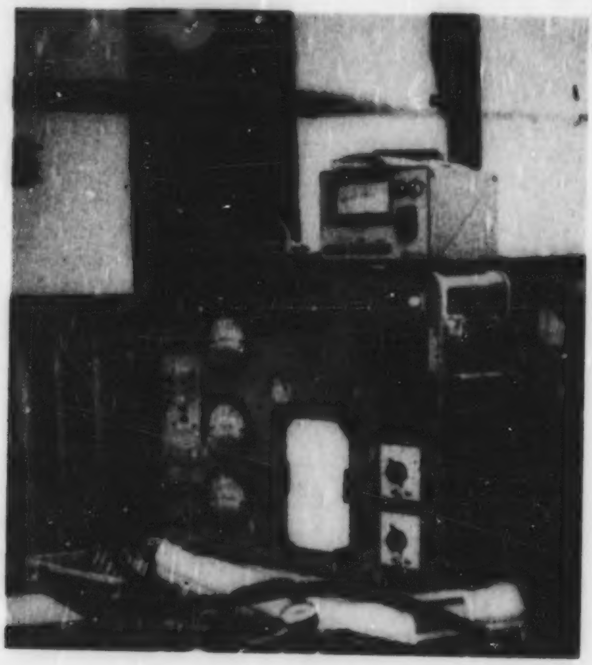
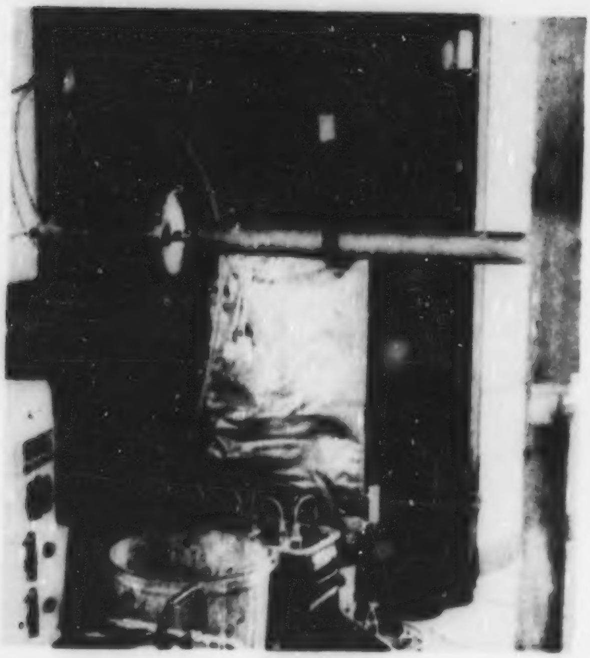


Port A



Port B

Figure 5-4. Main stack ports A and B.

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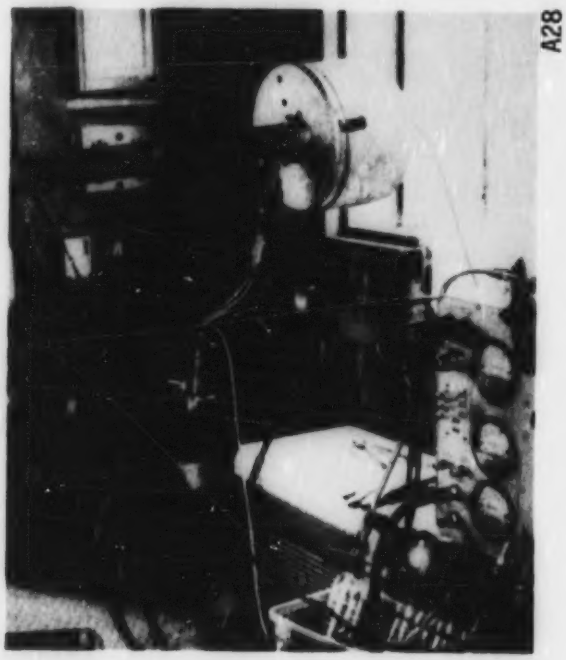
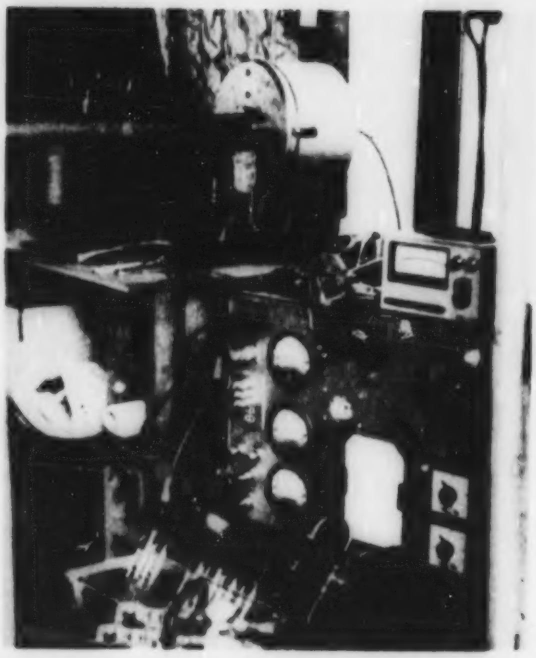


Port C



Port D

Figure 5-5. Main stack ports C and D.

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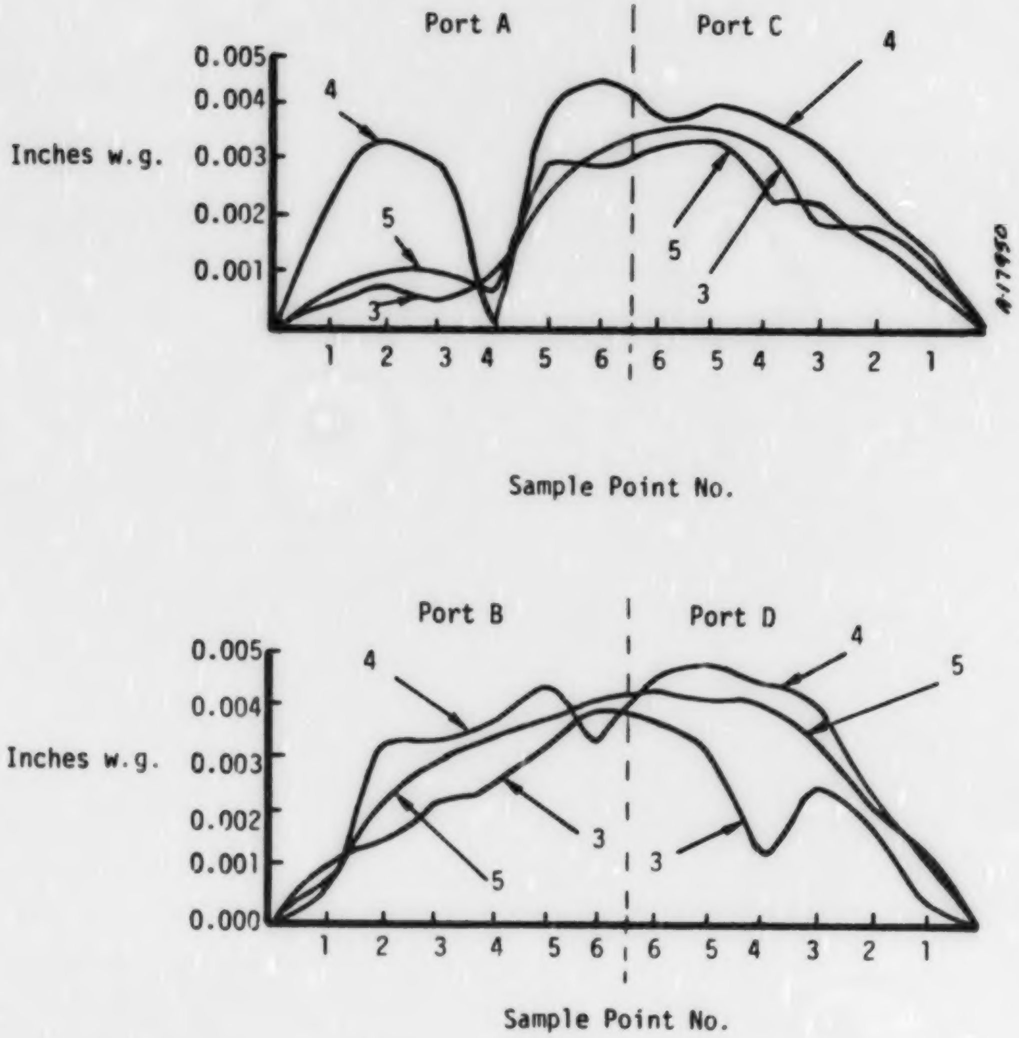

Note: Point 6 is actually point 5 repeated.
Numbers with arrows refer to test numbers.
Test 3, although invalid, has valid velocity data.

Figure 5-6. Reverberatory furnace Tests 3, 4 and 5 velocity profile.

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An examination of the following equation, used to calculate the flowrates required for isokinetic sampling, will illustrate this:

$$\Delta H = \frac{60^2\eta^2N_d^4K_p^2C_v^2(1 - B_{wo})^2P_sM_d}{576^2{}_o{}^2M_sP_m} \frac{T_m}{T_s} \Delta P$$

where

ΔH = inside diameter of the sampling nozzle, inches

K_p = constant, 85.48 (ft/sec) [(lb/lb-mole-°R)(in. Hg/in. H_2O)]$^{1/2}$

C_v = S-type pitot tube coefficient, dimensionless

T_s = absolute stack gas temperature at the sampling point, °R

ΔP = stack gas velocity head at the sampling point, inches H_2O

P_s = absolute stack gas pressure, inches Hg

M_s = molecular weight of the stack gas on wet basis, lb/lb-mole

B_{wo} = proportion by volume of water vapor in stack gas, dimensionless

P_m = absolute gas pressure at the orifice meter, inches Hg

T_m = absolute gas temperature at the orifice meter, °R

M_m = molecular weight of the gas at the orifice meter, lb/lb-mole

k_o = constant determined by calibration, (ft^3/min)[(lb/lb-mole-°R)(in. Hg/in. H_2O)]$^{1/2}$

M_d = molecular weight of the stack gas on dry basis, lb/lb-mole

Since the term $(1 - B_{wo})$ is squared, it has a significant effect on the isokinetic sampling rate (ΔH). For example, if the moisture content of the stack gas is determined to be 12.7 percent and changes by 5 percent (a change in B_{wo} of 0.05), $(1 - B_{wo})^2$ will change from 0.852 to 0.677 – and ΔH will change by 11 percent. Changes in the moisture content of the stack gas cannot be predicted unless a preliminary moisture measurement is made prior to each test. However, this was not done on the main stack due to time limitations.

To find the isokinetic sampling rate, the above question is solved by inserting:

- Measured values (M_s, M_d, B_{wo}, T_m, P_m) determined during the preliminary measurements using Methods 3 and 4
- Calibration constants (C_v, K_o) determined in the laboratory
- Measured values (P_s, T_s, ΔP) determined using Method 2
- Various values of nozzle diameter (N_d)

This calculation also determines the size of sampling nozzle needed to sample isokinetically over the entire range of ΔP in a particular duct, at a rate which will satisfy criteria of 60 scf total volume of gas sampled in the 60 minutes available for sampling.

After a number of these calculations are completed, the equation is reduced to the following form:

$$\Delta H = K \Delta P$$

where K is a numerical constant. Having determined K, the operator of the control module prepares a table of values of ΔP versus ΔH for use during the actual stack test. Then, during a test the operator reads the ΔP measured by the S-type pitot tube, finds the corresponding value of ΔH required for isokinetic sampling from the table, and adjusts the sampling rate to provide the required ΔH across the orifice meter.

Once the preliminary measurements and calculations have been completed, the actual stack tests can be conducted. Sampling procedures used during the actual test periods are described below.

5.1.2 Methods 5 and 8 Testing Procedures

The sampling train preparation was done in a clean laboratory provided by Kennecott to minimize contamination during preparation and recovery.

The train was prepared by washing all components exposed to the sample in Alconox and water, then rinsing with reagent grade acetone. The components were allowed to air dry before changing and assembly. The impingers were charged with measured volumes of reagent grade chemicals as described in Section 4.1.7. The silica gel was weighed before charging. Chemicals were prepared fresh daily to ensure complete absorption of gas species. The Method 5 and Method 8 filter holders were charged with their respective preweighted filters. The impinger train was assembled with the Method 8 filter holder between the second and third impingers, and the impinger train inlet and outlet were sealed with parafilm. The ends of the nozzle, probe, Method 5 filter, and sample-bearing hoses and extensions were sealed with parafilm. All test equipment was transported to the test site for final assembly and checkout.

Preliminary checks and measurements were made as follows. While the particulate sampling train was used in one sample port, the combined gas composition and moisture train was used in another sample port, so that measurements were made simultaneously. The particulate sampling trains traversed the stacks, while the gas composition and moisture trains remained at a fixed sampling point.

In addition, the sampling crews leak checked the sampling trains before each test by fastening a blank swagelok to the end of the probe, drawing a 15-inch Hg vacuum on the system, and recording the movement of the dry gas meter needle for 1 minute. If the leak rate was greater than 0.02 cfm, the source of the leak was found, corrected, and another leak check was performed.

The magnehelic gages and pressure transducer for ΔP and ΔH were then zeroed and levelled and all data specified by EPA Methods 5 and 8 were recorded on standard data sheets.

After the equipment was readied, the supervisor notified the crew leader of the status of the process. Since EPA Region IX specified that all tests must take place during the copper blow portion of the converter cycle, the supervisor was stationed at the acid plant control room at the beginning of each test to inform the crew leader of the start of copper blow. The test crew leader then began sampling. Normally, the sampling train was started within approximately 5 minutes after copper blow.

During the test, the supervisor toured the smelter to observe various parts of the operation to insure that normal operating conditions prevailed. He also observed the sampling practices of the test crew to insure the tests were being conducted in accordance with Methods 5 and 8.

During each test, the sampling crew observed the following procedures:

- Allow the sampling train to heat up to 250°F

- Position the pitot tube and nozzle to face directly into the gas streamline lines in the duct or stack
- Seal the sampling probe in the sample port
- Measure the ΔP at the sampling point, calculate ΔH required for isokinetic sampling, and set this value on the orifice magnehelic gage (proportional sampling was used for gas moisture)
- Record all the required data on the pertinent data sheet
- Maintain isokinetic conditions throughout the traverse

After a traverse was completed, the sampling train was moved to the exit sample port. In the case of instack/outstack filter testing on the reverb main stack, the instack 47-mm filter plugged rapidly and had to be changed after each port was sampled. If the sampling train was disassembled during the transfer, a leak check was made before starting the next traverse. The procedure described above was repeated for all tests.

At the conclusion of a test, the sampling train was removed from the duct or stack and was allowed to cool down. The impinger train was disconnected and purged for 10 minutes with ambient air to transfer any SO_2 retained in the 80-percent IPA into the H_2O_2 solution. When the components were cool enough to handle, the sampling train was disassembled at the test site. As soon as a component was removed, its inlet and outlet were sealed by stretching parafilm over the openings to prevent contamination of the sample by fugitive dust at the sampling site or during transit to the lab. The various components (nozzle, probe, filter holder, impinger train from Methods 5 and 8, and Tedlar bag and impinger train samples from Methods 3 and 4) were then transported to the laboratory for sample recovery and analysis.

5.1.3 Methods 3 and 4 Testing Procedure

The composition and moisture content of the stack gases were measured using the combined EPA Method 3 and 4 sampling train. The combined sampling train, consists of a sampling nozzle, a 5-foot heated probe (300°F to 325°F) with a stainless steel liner and an S-type pitot tube, a 142-mm filter holder (unheated) attached to the end of the probe, and other components. Prior to this test, a measured volume of distilled water and a known weight of silica gel had been put into the impinger train in the laboratory. At the sampling site, the sampling train was assembled and the moisture portion of the train was checked for leaks at 15 inches Hg vacuum by plugging the probe inlet (using a blank swagelok) and the tee connection to the Tedlar bag. The Tedlar bag was then leak checked separately, evacuated, and connected to the tee in the impinger train.

To make a run, the sampling probe was positioned at a point of average velocity, and appropriate data were recorded on data sheets. At the completion of the run, the equipment was disassembled and the impinger train, Tedlar bag, and 142-mm filter holder were taken to the laboratory for sample recovery.

5.2 SAMPLE RECOVERY, HANDLING, AND CHAIN OF CUSTODY

The following procedures were used to recover the samples from the Methods 5 and 8 trains and the Methods 3 and 4 trains, process the samples, and ship them to Aerotherm as necessary for chemical or gravimetric analysis.

5.2.1 Sample Recovery Procedures for Methods 5 and 8 Trains

Particulate matter was recovered from the sampling nozzle, sampling probe, and filter holders of the Methods 5 and 8 sampling train. After removing the parafilm cover from the inlet and outlet openings of the sampling nozzle and probe, both components were rinsed with reagent grade acetone, brushed with a nylon brush and rinsed again with acetone. This procedure was repeated at least twice until the rinse solution appeared clean to the naked eye. These acetone washings were put into a polyethylene bottle labeled with the following information: date of test, the test number, the type of sample, and the test location.

After particulate samples had been recovered from the sampling nozzle and probe, the filter holder was opened with the inlet side facing upwards. The 142-mm filter (47-mm instack filter) was then removed from the holder with a pair of tweezers and returned to the original labelled petri dish from which it had been taken. In some instances, fibers from the filter adhering to the surface of the filter holder had to be scraped off with the tweezers. In doing this, care was taken not to remove the teflon coating on the filter holder. The petri dish containing the used 142-mm filter was sealed with tape and labelled a second time with the date of the test, the test location, and the test number.

After the filter had been removed, the internal surfaces of the filter holder were rinsed with reagent grade acetone and brushed with a nylon brush. These acetone washings were added to the polyethylene bottle containing the probe and nozzle washings. Washings of the nozzle, instack filter holder, probe and the front half of the outstack filter holder were inadvertently combined into one sample for reverb Tests No. 6 and No. 7. Sample bottle caps were screwed on tightly and tape was wound around the cap to insure that the bottle did not leak. Labelled sample bottles and petri dishes were then set aside in numbered shipment boxes and the numbers recorded to identify which samples were shipped in which boxes.

After recovering the particulate sample from the front half of the sampling train, the test crew proceeded to recover the SO_3/H_2SO_4 and SO_2 samples from the back half of the train. The contents of Impingers No. 1 and No. 2 were transferred to a polyethylene sample bottle. These impingers were then thoroughly rinsed with an 80-percent IPA solution and the washings put into the polyethylene bottle. The backup filter holder which contained the 50-mm glass-fiber filter was disassembled and the filter added directly to the polyethylene sample bottle. The front half of this glass filter holder was then rinsed with 80-percent IPA solution and these washings also added to the sample bottle. The top for this bottle was screwed on tightly and tape was wound around the cap.

The same basic procedures were used to recover the H_2O_2 sample solutions in Impingers No. 3, No. 4, and No. 5. The solutions from Impingers No. 3 and No. 4 were transferred to a labelled polyethylene sample bottle along with any condensed liquid from Impinger No. 5. The back half of the backup filter holder and the internal surfaces of Impingers No. 3, No. 4, and No. 5 were then thoroughly washed with distilled water, and the washings were added to the sample bottle. As before, the cap to the sample bottle was screwed on tightly and taped. The date of the test, the test number, the type of sample and the test location were all recorded on the label. Both the IPA and H_2O_2 sample bottles were then set aside in a numbered shipment box, and the information on the labels of these two bottles — as well as the shipment box number — recorded.

5.2.2 Sample Recovery Procedures for Methods 3 and 4 Trains

The integrated sample of the stack gas collected in the tedlar bag was taken to the laboratory for analysis with the Orsat analyzer. The tedlar bag was connected directly to the Orsat analyzer and the gases pumped into the burette. The burette and the glass tubing of the Orsat were then purged three times with the gases in the tedlar bag to condition the internal surfaces of the Orsat. A measured volume (100 ml) of the gases was then drawn into the burette and sequentially passed through three fresh absorption solutions which removed CO_2, O_2, and CO in that order. Several passes were made through each solution to insure quantitative capture of each gaseous species. The results of this analysis were recorded on the appropriate field data sheet, and the tedlar bags were pumped out and made ready for use on the next test.

Since no chemical analysis of the moisture train samples was required, recovery of the moisture from the combined Methods 3 and 4 sampling trains took place in the field. At the completion of a test, the moisture sampling train was disassembled. The flexible teflon hose which connected the probe and filter to the impinger train (immersed in the ice bath) was then drained into a labelled polyethylene sample bottle to insure that no condensed water remained in the hose. Each of the impingers containing condensed water was also emptied into the same sample bottle. The cap for the bottle was screwed on tightly and the bottle was set aside for transportation to the lab. Separate sample bottles — the same ones that were used to transport distilled water and fresh silica gel to the sample site prior to the test — were used to store the used distilled water and the spent silica gel.

After the sealed sample bottles had been transported to the laboratory, the volume of water in the first sample bottle was measured with a graduated cylinder and recorded on the stack gas moisture data sheet. The weight of the spent silica gel in the second sample bottle was measured on a triple beam balance and also recorded on the data sheet. The water and silica gel were then discarded. The sample bottles were cleaned out, dried, and charged with measured amounts of distilled water and silica gel for the next test.

5.2.3 Sample Handling and Chain of Custody Procedures

After the samples had been recovered in the laboratory, they were placed in sealed, labeled containers. Once a shipment box had been filled with samples, it was sealed and labeled, then stored in a locked area (laboratory or motel room) until the end of the test series. The sample shipment boxes were then shipped by truck to Aerotherm in Mountain View, California.

All sample shipments were received in good order by Aerotherm's shipping and receiving department and transferred to the Source Evaluation Laboratory. The samples were stored in this locked laboratory for chemical analysis. When inspected by the analyst, none of the boxes appeared damaged and all were still sealed. Examination of the contents of each box showed that all sample bottles were still sealed with tape and were undamaged.

Throughout the analysis program, all samples were kept in their sample containers and stored in the analytical balance room or the Source Evaluation Laboratory. Both of these facilities are locked, and admittance is restricted to authorized personnel.

Since the completion of the analysis program, all samples are now being stored in sealed sample containers in Aerotherm's Source Evaluation Laboratory. These samples can be retained for evidence and analyzed at a later date to determine their chemical composition. In addition, used filters from the combined Methods 3 and 4 sampling trains are also being stored and can be analyzed immediately, if desired, since they are not required for evidence.

5.3 ANALYTICAL PROCEDURES

The following procedures were used to weigh the filters, dry and weigh the acetone washings, and analyze the impinger solutions for sulfuric acid and sulfur dioxide.

5.3.1 Particulate Weights

After the completion of each test, all the filters used in the combined Methods 5 and 8 sampling trains were sealed in petri dishes for shipment to Aerotherm. During this shipment, some of the particulate on the surface of the glass fiber filters was dislodged into the petri dish. To recover the loose particulate in the petri dish, the lid of the dish was first rinsed with a small amount of distilled water to remove any particulate adhering to the surface and then wiped dry. Next, the glass filter was removed from the petri dish, and the dish rinsed with distilled water and wiped clean. The washings from the petri dish were added to the polyethylene sample bottle containing the acetone washings from the probe, nozzle, and filter holder for that particular test.

After the loose particulate in the petri dish had been recovered, the glass fiber filter was transferred to the bottom half of the petri dish. The dish was then put into a desiccator containing silica gel and desiccated for at least 24 hours. After desiccation was complete, the filter and petri dish were transferred to a small, portable desiccator. They were then taken to the balance room to be weighed on a Mettler Model H20 analytical balance which had been levelled and zeroed. The 142-mm filter paper was removed from the desiccator with tweezers and folded in half twice so that it would fit on the balance pan.

The filters from the acid plant tests did not pick up moisture and could be readily weighed. However, the filters from the reverb furnace tests had collected some hygroscopic material and were gaining weight very rapidly by absorbing water vapor from the air. As a result, no attempt was made to determine the exact weight of the filters at that point. Instead, an approximate weight was determined as rapidly as possible, and each filter was returned to its petri dish and was desiccated for another 24 hours.

After being desiccated a second time, the filter was ready to be weighed accurately. When the approximate weight of the filter had been set on the balance, the filter was placed on the balance pan. The analyst immediately started a stopwatch, and the weight of the filter was measured and recorded 10 to 20 seconds after the filter was placed on the pan. As each filter gained weight by absorbing water vapor, the analyst continued to take readings until the filter reached equilibrium — up to 24 hours for some filters.

After completing the weight versus time curve, the analyst returned the filter to its petri dish, labelled the dish with a gross weight, and returned the sample to the Source Evaluation Lab for storage pending further instructions from EPA Region IX.

The polyethylene sample bottle containing the acetone washings from the sampling nozzle, the sampling probe, and the filter holder (including the instack filter holder and front half of the outstack filter holder for Tests 6 and 7 on the reverb) — as well as the distilled water washings from the petri dish — was open and placed in the fume hood. The sliding window of the hood was partially closed and the fume hood fan turned on to circulate laboratory air through the hood. After the acetone in the sample bottle had evaporated until approximately 5 ml of acetone remained in the bottle, the slurry was transferred to a tared beaker (usually 10- to 30-ml beaker with a small tare weight) and evaporated to dryness in the fume hood. Because of the presence of water in the original sample (petri dish washings), many of the samples did not evaporate to total dryness. In these cases, the beakers were placed on a steam bath and evaporated to dryness.

After evaporation, each beaker was transferred to the desiccator for 24 hours. The tared beaker was then transferred to the portable desiccator and taken to the balance room. Unlike the particulates on some of the glass fiber filters, the residues were not hygroscopic and could be weighed directly. After the weight of each sample was recorded in the filter record book, the samples were stored in the Source Evaluation Laboratory pending further instructions from EPA Region IX.

5.3.2 Impinger Solution Analysis

Before titrating the isopropanol solutions containing SO_3/H_2SO_4, certain standardizations were carried out in the laboratory. The analyst (Atkins) used a 1 N NaOH Acculute Standard volumetric solution from Anachemia Chemicals Limited to prepare a 0.01 N NaOH standardization solution by dilution with deionized water. Several titrations using this NaOH standardization solution were used to repeatedly standardize the analytical reagent grade 0.01 N H_2SO_4 from Baker Chemicals. After the sulfuric acid solution had been standardized against the standard sodium hydroxide solution, the 0.01 N H_2SO_4 solution was in turn used to standardize the barium perchlorate solution. As before, this standardization check was done repeatedly and the average of several titrations was used to calculate the average normality of the $Ba(ClO_4)_2$ solution.

As a further check on the accuracy of the standard NaOH solution, it was standardized against a primary standard potassium acid phthalate solution from Baker Chemicals. The $KHC_8H_4O_4$ was dried in an oven at 105°C to 110°C for 1 hour and then allowed to cool in a desiccator. An accurately weighed amount was then added to a flask and dissolved in boiling deionized water. The solution was allowed to cool to room temperature and phenolphthalein indicator was added. When this primary standard solution was used to verify the accuracy of the standard NaOH solution, the maximum deviation between the two solutions was 0.0002.

The 50-ml buret used for all titrations was also calibrated. The buret was filled with water and a measured volume of water was delivered into a tared container. The container was then stoppered and weighed on the Mettler balance. The ambient temperature was recorded to convert the mass of water to volume, using data from Introductory Qualitative Chemistry by Olson, Koch, and Pimental. Since the difference between the delivered volume and the calculated volume was less than 1 percent in all cases, no correction factor for the buret reading was necessary. The same procedure was used to calibrate the pipets used in the titrations. Again, no correction factors were required. After performing all these standardization and calibration checks, the analyst was now prepared to perform the titrations of field samples.

After the sample bottles containing the isopropanol solutions were shaken to make sure the solution was homogeneous, a measured aliquot (varying from 1 ml to 100 ml) was transferred to a flask with a calibrated pipet. Two to four drops of thorin indicator were then added and the aliquot was titrated with the standardized barium perchlorate solution to the pink end-point. In addition, a blank (isopropanol and deionized water) of approximately the same size aliquot was titrated in a similar manner. The following data was recorded in the analytical log book:

- The volume of barium perchlorate titrant used to titrate the aliquot
- The volume of barium perchlorate titrant used to titrate the blank
- The normality of the barium perchlorate titrant

- The total solution volume of sulfuric acid (first two impingers and filter)
- The volume of the aliquot titrated

Each aliquot was titrated twice.

After the sample bottles containing thehydrogen peroxide solutions were shaken to make sure the solution was homogeneous, a measured aliquot (varying from 1 ml to 25 ml) was transferred to a flask with a calibrated pipet. A total of 100 ml of isoproponol and two to four drops of thorin indicator were added to the aliquot, which was then titrated to a pink endpoint using the standardized barium perchlorate solution. The following data were recorded in the analytical log book:

- The volume of barium perchlorate titrant used to titrate the aliquot
- The normality of the barium perchlorate titrant
- The total solution volume of sulfur dioxide (third and fourth impingers)
- The volume of the aliquot titrated

These titration data were used to calculate the concentrations of SO_3/H_2SO_4 and SO_2 in the various gas streams.

5.3.3 Orsat Analysis

All gas samples were analyzed in the field laboratory at Kennecott with an Orsat gas analyzer. As required by EPA Method 3, each bag was sampled until three consecutive analyses varied by no more than 0.2 percent for each component analyzed (CO_2,O_2, CO).

APPENDIX A

DAILY ACTIVITIES

APPENDIX A

DAILY ACTIVITIES REPORT

Day No. 1, August 2, 1976

1. Left Tucson and drove to Hayden, Arizona. Arrived at Kennocott Copper Smelter at 9:40 a.m. Crew met with Messrs. Matheson, Fitch, Mortimer to discuss the tests.
2. Kennecott indicated that no testing could be done at the acid plant since the additional platform required to test the second sampling port had not been installed on the stack.
3. Safety rules were reviewed and discussions were held with Stuart Nebuker regarding reverb furnace operations and process data collection.
4. Kennecott personnel were experiencing some operating problems at the reverb and it was scheduled to be down on 8/3/76 and possibly on A-shift of 8/4/76. Steiner, Sutton (process observed for Aerotherm) and Fitch (Kennecott Environmental Department) went on a tour of the various control rooms while the remainder of the test crew unloaded the sampling equipment.
5. Control rooms visited — Reactor (Roaster), Reverb, Reverb ESP Electronics, Converter Aisle, and Acid Plant.
6. Lloyd Kostow of EPA Region IX arrived at 12:20 p.m.; crew ate lunch and began preparations for making preliminary measurements (velocity and temperature traverses, stack gas composition and moisture content) of reverb furnace stack gases. Kostow, Sutton and Kearney (Kennecott Environmental Department) went through the process again to make a list of the process parameters to be recorded during the stack testing period.

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7. Tare weight of bottle for silica gel was 63.6 gm and the weight of the bottle plus silica gel was 283.9 gm.

8. At 5:30 p.m., the crew arrived at the sampling platform on the reverb furnace stack to start the preliminary measurements. The stack circumference was measured with a rope and was 98.5 ft. Sampling ports were labelled A, B, C, and D starting at the elevator and going clockwise. The distance from the sampling platform to the top of the breeching entering the base of the stack was 169 ft. as measured by a weighted rope.

9. The following stack wall thickness measurements were made:

A-port:	21.5 inches including pipe nipple
	18 inches not including pipe nipple
D-port:	26 inches including pipe nipple
	18.6 inches not including pipe nipple
C-port:	23.5 inches including pipe nipple
	18 inches not including pipe nipple
B-port:	not measured

Since the inside brick work had broken away during the installation of the sampling ports, the exact wall thickness was difficult to determine. The measurement made at A-port was deemed to be more reliable and a value of 18 inches was used for wall thickness.

10. The outside radius of the stack was calculated to be 15.68 feet; the inside radius was calculated to be 14.18 feet; the sampling ports were 6 diameters downstream of the breeching and much greater than 2 diameters from the stack exit.

11. The sampling point locations were marked on the probe. Since the sampling probe was 10 feet long (unirails at Kennecott could not support a longer probe), the inner most sampling Point (No. 6) could not be reached which necessitated sampling Point No. 5 twice.

12. At 6:55 p.m., the crew started the preliminary measurements and obtained the following data:

    - D-port: No. 1 – 230°F, 0.0012 to 0.0020 inch H_2O
      No. 2 – 265°F, 0.0012 to 0.0020 inch H_2O
      No. 3 – 291°F, 0.0028 to 0.0040 inch H_2O
      No. 4 – 300°F, 0.0008 to 0.0020 inch H_2O
      No. 5 – 300°F, 0.0008 to 0.0028 inch H_2O
    - C-port: No. 1 – 254°F, 0.0072 inch H_2O
      (7:15 p.m.) No. 2 – 290°F, 0.0056 to 0.0068 inch H_2O
      No. 3 – 295°F, 0.0080 inch H_2O
      No. 4 – 298°F, 0.0052 inch H_2O
      No. 5 – 301°F, 0.0048 inch H_2O
    - B-port: No. 1 – 241°F, 0.0060 to 0.0080 inch H_2O
      (7:33 p.m.) No. 2 – 291°F, 0.0040 to 0.0060 inch H_2O
      No. 3 – 294°F, 0.0040 to 0.0056 inch H_2O
      No. 4 – 298°F, 0.0016 inch H_2O
      No. 5 – 299°F, 0.0016 inch H_2O
    - A-port: No. 1 – 242°F, 0.0070 inch H_2O
      (7:52 p.m.) No. 2 – 266°F, 0.0066 inch H_2O
      No. 3 – 273°F, 0.0072 inch H_2O
      No. 4 – 208°F, 0.0036 inch H_2O
      No. 5 – 296°F, 0.0044 inch H_2O

13. After completing the preliminary measurements the crew returned to the Kennecott Laboratory with the stack gas composition bag sample and the moisture train sample. These samples would be analyzed the following day since the smelter was going to be down.

Day No. 2, August 3, 1976

1. No testing was conducted on this day since the smelter was down for repairs.
2. Kostow and Steiner travelled to Inspiration Copper in Inspiration, Arizona to review their plans for conducting compliance tests.
3. Returned to Kennecott Laboratory by 2:15 p.m. to analyze the samples collected the previous day. The following results were obtained:

   H_2O condensed = 60 ml

   H_2O silica gel = 17.1 gm

   Moisture content = 7.09 percent by volume

CO_2	O_2	CO
4 percent	12.3 percent	0.8 percent
3.5 percent	13.4 percent	0.3 percent
4.2 percent	13.5 percent	0.4 percent

4. The solutions were changed in the Orsat analyzer to insure fresh chemicals were used for subsequent gas analyses.

Day No. 3, August 4, 1976

1. No testing was conducted on this day since the smelter was still down for repairs.
2. The preliminary measurement data was used to calculate appropriate sampling nozzle sizes and sampling rates.
3. Part of the sampling crew drove to Phoenix to purchase additional acetone.

Day No. 4, August 5, 1976

1. Arrived at Kennecott at 7:01 a.m. and photographed dust plume leaving the roof monitor of the building housing the reactor, reverb and converters.

2. Test crew made up fresh chemicals for use in the tests to be conducted; barometric pressure was 27.87 inch Hg; 4 sets of glassware were made to minimize trips between the stack and the lab.

3. Started Test No. 1 at 9:50 a.m. after successful leak check (0.05 cfm at 18 inch Hg) Sampling stared in Port B at Point No. 5 and the velocity was high, unstable and difficult to read. Point No. 5 and Point No. 6 were treated as the same point.

4. Impinger outlet temperatures could only be read at Points No. 4 and 5 because the thermocouple lead wire was too short.

5. Stack temperature profile was uniform across the stack and sampling port changes between traverses took ~30 minutes.

6. The following process observations were made during B-traverse:

Reactor	Start 83661.4
	Finish 836631.2
	Difference 19.8
	10:00 a.m. to 10:15 a.m. – reactor down due to underflow
Reverb	Gas flow = 21
	Air flow = 17
Acid Plant	SO_2 inlet = 7.9 percent
	Converters = 2 and 4 online

   Reactor and converters 2 and 4 were online until 10 minutes before the end of the traverse and then went offline.

7. A decision was made to change control modules for the next traverse because of the difficulty experienced in controlling oven temperature.

8. The sampling equipment was transferred to sampling Port A and a leak check of 0.002 cfm at 17 inches Hg was obtained. Velocity was lower and much more stable on this traverse.

9. After completing the traverse, the impinger train was purged (10 minutes) and replaced with another fresh impinger train.

10. The following process observations were made during A-traverse:

Reactor	
Reverb	Missed tonnage but everything running smoothly.
Acid Plant	

11. Moved sampling equipment to Port D and got a satisfactory leak check. Velocity seemed low during entire traverse.

12. At the beginning of sampling Point No. 2, an electrical short developed in the pump power cord: the sampling was stopped momentarily while the circuit breaker in the control console was reset and the short was repaired with tape.

13. The following process observations were made during D-traverse:

Reactor	Start 836743.7 Finish 836779.0 Difference 35.3 (~70 percent of design rate) Reactor log numbers (rate) taken on an hourly basis were steady all morning
Reverb	Gas flow = 21 Airflow = 17 Stack gas temperatures are higher than those measured during preliminary measurements; visible emissions from reverb stack due to poor combustion conditions
Acid Plant	SO_2 inlet = 5 percent Converters = No. 4 online

14. Moved sampling equipment to Port C and got an acceptable leak check. Stack gas temperature was uniform at ~300°F. The velocity was high in the center and decreased smoothly at the wall.

15. The following process observations were made during C-traverse:

Reactor Start 836821.0

Finish 836855.9

Difference 34.9

Reactor bed temperatures started increasing from 1:00 p.m. to 4:00 p.m. from 1100°F to 1240°F

Reverb Gas flow = 21

Airflow = 17

Reverb ESP

	AC Volts	AC Amps	DC mamps	Sparks/min
Outside No. 1 and No. 2	310	62	240	0
Inside No. 1 and No. 2	200	28	90	150
Middle No. 1 and No. 2	270	64	240	0
Middle No. 3 and No. 4	280	60	240	0
Inside No. 3 and No. 4	270	64	260	0
Outside No. 3 and No. 4	100	62	240	0

16. At 2:05 p.m. received a call from the reverb furnace control room indicating that opacity should improve because combustion conditions were changed in the reverb furnace.

17. Started Test No. 2 in Port C at 4:36 p.m. after a perfect leak check at 20 inches Hg. Static pressure in stack was -1.3 inch H_2O. The velocity was high and too much silica gel in the impinger train caused a high pressure drop; pump vacuum was 24 inches Hg and sampling may not be isokinetic.

18. The following process observations were made during C-traverse:

Reactor Start 837046.8

Finish 837065.1

Difference 18.3

Rate was ~4 percent at start and ~70 percent at finish

Reverb Gas flow = 21

Airflow = 17

Reverb outlet pressure = -0.51 inch H_2O

Acid Plant SO_2 inlet = 6 percent (just after first traverse)

Converters = No. 2 and No. 3 online

Reverb ESP	AC Volts	AC Amps	DC MA	Sparks/min
Outside No. 1, No. 2	310	63	240	0
Inside No. 1, No. 2	200	28	100	160
Middle No. 1, No. 2	275	64	240	0
Middle No. 3, No. 4	300	62	240	0
Inside No. 3, No. 4	270	62	190	50
Outside No. 3, No. 4	100	63	240	0

19. Moved sampling equipment to Port D; broke the silica gel impinger; replaced; got a perfect leak check at 16 inches Hg. Pump vacuum again climbed to 24 inches Hg so it was difficult to maintain isokinetic; at 5:05 p.m. fugitive emissions from the roof monitor were constant and a gas leak developed at the acid plant.

20. The following process observations were made during D-traverse:

Reactor	Start 837103.3
	Finish 837135.2
	Difference 31.9
	Reactor at ~75 percent rate at start and ~70 percent at finish; bed temperatures down to 1200°F from 1240°F
Reverb	Gas flow = 21
	Airflow = 17
	Outlet pressure = -0.051 inch H_2O
Acid Plant	SO_2 inlet = 2.2 percent
	Converters = No. 2, No. 3 online
Reverb ESP	Same as previous traverse

21. At the completion of the traverse, the impinger train was purged (10 minues) and replaced with another impinger train. Moved sampling equipment to Port A and got a good leak check at 20 inches. Pump vacuum still at 23 inches Hg so sampling was probably not isokinetic.

22. The following process observations were made during A-traverse:

Reactor	Start 837167.3 (65-percent rate)
	Finish 837200.5 (70-percent rate)
	Difference 33.2
	Reactor bed temperatures down to 1180°F
Reverb	Gas flow = 21
	Airflow = 17
	Outlet pressure = -0.051 inch H_2O
Acid Plant	SO_2 inlet = 4.4 percent
	Converters = No. 3 online

Combustion Gas Analysis – 7:30 a.m.: 0.6 percent CO

1.0 percent CO

Combustion Gas Analysis – 1:30 p.m.: 1.2 percent CO

2:00 p.m.: 0.4 percent CO

23. Moved sampling equipment to Port B and got a good leak check at 27 inches Hg. At 6:42 p.m., fugitive emissions from roof monitor and acid plant were photographed by Fitch (Kennecott). At 7:45 p.m. the continuous velocity monitor (Haystings-Raydist) was not giving the same readings as our pitot-tube and pressure transducer. Problem was traced to a defective umbilical cord which was kinked and gave higher than actual velocity readings during the entire test. A new umbilical cord was substituted and both the continuous velocity monitor and our pitot-tube/pressure transducer now gave identical velocity readings. Purged impinger train for 10 minutes and returned to the laboratory for sample recovery.

24. The following process observations were made during B-traverse:

Reactor Start 837246.1 (70-percent rate)

Finish 837280.0 (68-percent rate)

Difference 33.9

Bed temperatures up to 1240 to 1260°F

Reverb Gas flow = 21

Airflow = 17

Outlet pressure = -0.051 inch H_2O

25. Brought samples to laboratory and began sample recovery for Test No. 1 and obtained the following results:

- Good seal on 142-mm filter; filter dark green in color with no penetration; filter did not stick to filter holder; did not wash filter holder

- Moisture train filter had same dark green color around outside edges but more yellow in center

- Volume of H_2O condensed = 86 ml; silica get collected 37.1 gm of H_2O
- IPA impingers — solid brown particles floating in IPA on first impinger; tip covered but solution was pale brown in color; second impinger tip covered, solution clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — tips covered and solutions were clear

26. The crew left the plant at 9:00 p.m.

Day No. 5, August 6, 1976

1. Arrived at plant at 7:00 a.m. and went to lab to complete sample recovery of previous day's tests.
2. The following data was obtained for Test No. 1:

CO_2	O_2	CO
4.2 percent	13.4 percent	0.9 percent
4.2 percent	13.4 percent	0.4 percent
4.2 percent	13.5 percent	0.4 percent
4.2 percent	13.5 percent	0.4 percent

Second train
- IPA impingers — first impinger solution pale yellow in color, tip covered, solid particles suspended in solution; second impinger solutionpale milky white in color; tip covered
- 50-mm filter — white, not wet
- Glass frit — yellow stain which would not wash off with IPA

- H_2O_2 impingers — tips covered, solutions clear

3. The following data was obtained for Test No. 2:

- H_2O condensed = 73 ml; silica gel trapped 54.4 gm of H_2O
- No gas analysis for Test No. 2 since sample leaked out of tedlar bag

First train

- IPA impingers – first impinger solution pale yellow in color, tip covered, no suspended solids; second impinger solution pale yellow in color, tip covered, no suspended solids
- 50-mm filter – slight yellow color
- H_2O_2 impingers – tips covered, solutions clear

Second train

- IPA impingers – first impinger solution pale milky white in color, tip covered; second impinger solution pale yellow in color, tip covered, solution clear
- 50-mm filter – slight yellow color
- H_2O_2 impingers – tips covered, solutions clear

4. Fresh chemicals were prepared for the tests and the crew were setting up the sampling equipment on the stack by 11:00 a.m. Got word from Kennecott that there are problems with reactor and it may be down on B-shift. Reactor and acid plant down at 11:40 a.m. then back on again.

5. Set up equipment at Port C and got a good leak check; started testing at 11:47 a.m.; velocity looks normal and pump vacuum is only 6 inches Hg.

6. The following process observations were made during C-traverse:

   Reactor
   Start 837969.6 (70-percent rate)
   Finish 838000.7 (60-percent rate)
   Difference 31.1
   Bed temperatures halfway through traverse were 1130 to 1170°F

   Reverb
   Gas flow = 21
   Airflow = 17
   Outlet pressure = 0.06 inch H_2O

7. Called at 12:01 p.m. to check on Haystings Raydist reading – 208 to 210 fpm; checked data from C-traverse and calculated 194 fpm using pitot tube and pressure transducer.

8. Moved equipment to Port D and got an acceptable leak check; traverse went very smooth and the impinger train was purged for 10 minutes after the traverse.

9. The following process observations were made during D-traverse:

   Reactor Start 838030.8 (60-percent rate)
   Finish 838060.0
   Difference 29.2
   Bed temperatures up 1170 to 1200°F

   Reverb Gas flow = 21
   Airflow = 17
   Outlet pressure = -0.06 inch H_2O
   Gas analysis = 9.8 percent CO_2/SO_2; 0.4 percent CO

   Acid Plant SO_2 inlet = 1.2 percent
   Converters = None online

10. Moved equipment to Port A and installed a fresh impinger train; got an acceptable leak check; very low velocity in stack and oven temperature is less than 250°F.

11. The following process observations were made during A-traverse:

   Reactor Start 838110.0 (65-percent rate)
   Finish 838140.0
   Difference 30.0
   Bed temperature up 1230 to 1260°F

   Reverb Gas flow = 21
   Airflow = 17
   Outlet pressure = -0.06 H_2O

   Acid Plant SO_2 inlet = 0

Reverb ESP		AC Volts	AC Amps	DC MA	Sparks/min
	Outside No. 1, No. 2	320	63	240	0
	Inside No. 1, No. 2	200	28	100	150
	Middle No. 1, No. 2	270	64	240	0
	Middle No. 3, No. 4	300	62	240	0
	Inside No. 3, No. 4	270	63	250	0
	Outside No. 3, No. 4	100	64	240	0

12. Moved equipment to Port B and got a good leak check. Encountered no difficulties during this traverse. At the completion of the traverse, the impinger train was purged for 10 minutes and the crew returned to the lab at 4:30 p.m. to begin sample recovery.

13. The following process observations were made during B-traverse:

Reactor	Start 838173.4 (60-percent rate)
	Finish 838204.0
	Difference 30.6
Reverb	Gas flow = 21
	Airflow = 17
	Skimmer's report indicated five matte taps delivered
Acid Plant	SO_2 inlet = 0.6 percent
	Converters = No. 2 online
Reverb ESP	Same as for A-traverse

16. The following gas composition and moisture results were obtained for Test No. 3:

CO_2	O_2	CO
3.7 percent	13.7 percent	0.4 percent
3.7 percent	13.8 percent	0.4 percent
3.8 percent	13.8 percent	0.4 percent

H_2O condensed = 148 ml

H_2O in silica gel = 27.3 gm

Moisture content = 11.4 percent

17. The following observations were made recovering the samples from the trains:
    - 142-mm filter – good seal, no penetration, brown in color
    - Flexible hose – had a lot of condensed particulate in it
    - IPA impingers – first impinger was murky, tip covered; second impinger was clear, tip covered
    - 50-mm filter – white, not wet
    - H_2O_2 impingers – tips covered, solutions clear
18. On the advice of Kennecott personnel (Fitch), no further tests were conducted and the crew left the plant.

Day No. 6, August 9, 1976

1. Arrived at plant at 6:55 a.m. and noticed fugitive emissions in roof monitor -- operational problems may still be present.
2. Crew proceeded to lab to charge sampling trains with new chemicals; barometric pressure was 27.81 inches Hg; Fitch informed us the acid plant was down for repairs on 8/7/76 and everything should be okay.
3. Arrived at the reverb stack at 9:00 a.m. and began setting up the equipment.

4. Started testing at 10:57 a.m. in Port C after a good leak check; static pressure was -1.3 inch H_2O; no difficulties with traverse.

5. The following process observations were recorded during C-traverse:

Reactor	Start 841025.0 (63-percent rate)
	Finish 841053.1 (65-percent rate)
	Difference 28.1
	Bed temperatures were 1200 to 1210°F
Reverb	Gas flow = 21
	Airflow = 17
	Gas analysis = 10.2 percent SO_2/CO_2, 0.8 percent CO
Acid Plant	SO_2 inlet = 8.5 percent
	Converters = No. 3, No. 4 online
Reverb ESP	Okay

6. Moved equipment to Port D and had a good leak check; velocities slightly higher than previous traverse and stack temperatures were slightly lower.

7. At the completion of the traverse, the impinger train was purged (10 minutes), and replaced with another train.

8. The following process observation were recorded during D-traverse:

Reactor	Start 841087.1 (65-percent rate)
	Finish 841124.6
	Difference 27.5
	Bed temperatures were low (1130 to 1150°F)
Reverb	Gas flow = 21
	Airflow = 17
	Outlet pressure = -0.06 inch H_2O

9. Moved equipment to Port A and had a good leak check; stack gas temperatures increased (>290°F); a drop in velocity to zero was

noticed at Point No. 4 which lasted about 5 minutes and the conditions returned to normal.

10. The following process observations were made during A-traverse:

Reactor Start 841157.8 (65-percent rate)
Finish 841200.0 40 min. not 30 min.
Difference 42.2
Reverb Gas flow = 21
Airflow = 17
Outlet pressure = -0.06 inch H_2O
Acid Plant SO_2 inlet = 7.8 percent
Converters = No. 3, No. 4 online
Reverb ESP Okay

11. Moved equipment to B-point and had a good leak check; no difficulties experienced during this traverse; completed test and purged impinger train for 10 minutes; cleaned out the sampling probe on stack and replaced 142-mm filter with a new one.

12. The following process observations were made during B-traverse:

Reactor Start 841232.4 (55-percent rate)
Finish 841261.8 (64-percent rate)
Difference 29.4
Reverb Gas flow = 21
Airflow = 17
Outlet pressure = -0.06 inch H_2O
Acid Plant SO_2 inlet = 59 percent
Converters = No. 3, No. 4 online
Reverb ESP Everything normal

13. Moved equipment to C-port for the start of Run No. 5 and had a good leak check. Started heating oven at 3:27 p.m.; acid plant has visible emissions from stack and leak in the ductwork; roof monitor was smoking; start traverse at 3:40 p.m.

14. The following process observations were made during C-traverse:

Reactor Start 841365.8
Finish 841393.1
Difference 27.3

Reverb Gas analysis = 10 percent CO_2/SO_2, 1.0 percent CO

15. Moved equipment to Port D and had a good leak check; at the completion of the traverse, the impinger train was disconnected, purged and replaced with a new impinger train.

16. The following process observations were made during D-traverse:

Reactor Start 841418.1 (68-percent rate)
Finish 841450.9 (18-percent rate)
Difference 32.8
Bed temperatures 1100 to 1130°F

Reverb Gas flow = 21
Airflow = 17
Outlet pressure = -0.06 inch H_2O

Reverb ESP

	AC Volts	AC Amps	DC MA	Sparks/min
Outside No. 1, No. 2	320	62	240	0
Inside No. 1, No. 2	320	48	160	150
Middle No. 1, No. 2	260	60	240	100
Middle No. 3, No. 4	240	4	150	0

	AC Volts	AC Amps	DC MA	Sparks/min
Inside No. 3, No. 4	260	46	190	50
Outside No. 3, No. 4	100	63	140	0

17. Moved equipment to Port A and had a good leak check; stack gas temperatures decreased to ~285°F and velocities were slightly lower.

18. The following process observations were made during A-traverse:

Reactor Start 841494.3 (65-percent rate)
Finish 841526.1 (70-percent rate)
Difference 31.8
Bed temperatures from 1100 to 1150°F

19. Reverb Gas flow = 21
Airflow = 17
Outlet pressure = -0.06 inch H_2O

Acid Plant SO_2 inlet = 3.2 percent
Converters = none online (just reactor)

20. Moved equipment to Port B and had a good leak check; temperatures are up on this traverse and velocity was normal. After completion of the traverse, the impinger train was purged for 10 minutes; the crew returned the samples to the lab for recovery.

21. The following process observations were recorded during B-traverse:

Reactor Start 841550.2 (70-percent rate)
Finish No value

Reverb Gas flow = 21
Airflow = 17
Outlet pressure = -0.06 inch H_2O
Matte taps delivered = 5 on No. 3 converter
= 6 on No. 4 converter

Acid Plant SO_2 = 5.5 percent

Converters = No. 2, No. 4 online

22. The crew returned to the laboratory at 8:11 p.m. and the following data was recorded for Test No. 4:

- H_2O concensed = 120 ml
- H_2O in silica gel = 31.7 gm

CO_2	O_2	CO
4.3 percent	13.5 percent	0.2 percent
4.4 percent	13.6 percent	0.2 percent
4.3 percent	13.6 percent	0.3 percent

First train
- IPA impingers — first impinger solution slightly colored, some precipitate; second impinger solution clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — clear

Second train
- IPA impingers — first impinger solution dirty yellow color, some precipitate; second impinger solution clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — both clear

23. The following data were recorded for Test No. 5:

CO_2	O_2	CO
4.3 percent	13.6 percent	0.5 percent
4.3 percent	13.5 percent	0.6 percent
4.4 percent	13.4 percent	0.6 percent

First train
- IPA impingers — first impinger solution was clear; second impinger solution was grey
- 50-mm filter — dark grey color
- H_2O_2 impingers — both clear

Second train

- IPA impingers — first and second impinger solutions were clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — both clear

Day No. 7, August 10, 1977

1. A rearrangement of assignments occurred to accommodate the in-stack filter tests. Steiner left Hayden to witness particulate testing at Inspiration Copper in Inspiration, Arizona. Sutton relinquished his process observer duties to Lloyd Kostow of EPA Region IX and replaced Steiner in the test crew.
2. Upon arriving at the plant, the test crew prepared four sets of impingers, two 142-mm filter holders and four 47-mm instack filter holders.
3. Operational difficulties were encountered with the elevator servicing the sampling platform which caused delays.
4. The S-type pitot tube extensions were put on the sampling probe to accommodate the instack 47-mm filter holder and the sampling points were remarked on the probe.
5. Even with the pitot tube extensions on the probe, Point No. 6 could not be sampled. Test No. 6 began in Port C after a good leak check at 1:25 p.m. Points No. 5 and 6 were considered one point again.
6. Moved equipment to Port D and changed the instack 47-mm filter; leak check was acceptable; stack temperature increased to ~312°F during this traverse; the impinger train was disconnected and purged after this traverse was complete; a new impinger train was connected to the sampling train.
7. Moved equipment to Port A, changed the instack filter and got an acceptable leak check; it started to rain and a slight drop in stack temperature was noted (~303°F now).
8. Moved equipment to Port B, changed the instack filter and got a valid leak check. Stack gas temperature decrease to ~300°F. Velocity increased during the traverse.

9. At the completion of this traverse, the impinger train was purged and the various components were taken to the lab for sample recovery.

10. The following observations were recorded for Test No. 6:

    - 47-mm filters – all appeared to be wet because of the way they peeled off the support screen and tore apart
    - First train
        - IPA impingers – first impingers solution very slightly milky; second impinger solution clear
        - 50-mm filter – white, not wet
        - H_2O_2 impingers – clear
    - Second train
        - IPA impingers – first impinger solution light brown with particles; second impinger solution was clear
        - 50-mm filter – white, not wet
        - H_2O_2 impingers – clear

Day No. 8, August 11, 1977

1. Test crew went to the lab and prepared four impinger trains, four 47-mm instack filter holders and two 142-mm filter holders.
2. Upon arriving at the sampling platform, the crew cleaned the sampling probe from Test No. 6 and sent the flexible hose to the lab for cleaning.
3. Test No. 7 was started in Port C after a successful leak check at 10:45 a.m.; stack gas temperature had decreased to ~283°F.
4. Moved equipment to Port D, changed instack filter and got a valid leak check; after completion of traverse, the impinger train was disconnected, purged for 10 minutes, and replaced with a new train.
5. Moved the equipment to Port A, changed instack filter and got a good leak check; no change noted in stack gas temperature or velocity from previous traverse.
6. Moved equipment to Port B, changed instack filter and got a good leak check: stack gas temperature decreased to ~255°F. After

completion of the traverse, the impinger train was purged and the probe was cleaned out; the components were taken to the laboratory for sample recovery.

7. The following observations were made recovering samples for Test No. 7.

- 47-mm filters — all filters appeared to be wet because of the way they peeled off the support screen and tore apart.

First train

- IPA impingers — first impinger solution light white color; second impinger solution clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — clear

Second train

- IPA impingers — first impinger solution white; second solution was clear
- 50-mm filter — white, not wet
- H_2O_2 impingers — clear

8. Steiner returned to Kennecott at 4:00 p.m. and obtained the following results:

- H_2O condensed = 148 ml
- H_2O in silica gel = 27.5 gm

CO_2	O_2	CO	
4.3 percent	13.5 percent	0.3 percent	Test No. 7
4.2 percent	13.6 percent	0.3 percent	
4.2 percent	13.7 percent	0.4 percent	

CO_2	O_2	CO	
4.3 percent	13.8 percent	0.7 percent	Test No. 6
4.3 percent	13.8 percent	0 percent	
4.3 percent	13.8 percent	0 percent	
4.2 percent	14.0 percent	0 percent	

Day No. 9, August 12, 1976

1. The test crew packed up the sampling equipment and samples and drove to Phoenix. The equipment was put on the loading dock at Hughes Airwest Air Cargo terminal for shipment to San Jose. The collected samples were picked up by ONC for truck shipment to Mountain View. The crew flew home.

Day No. 1, December 14, 1976

1. The test crew, consisting of R. Larkin, C. Stanley, and E. Rice, is accompanied to the plant by Ms. Linda Wunder-Freet of EPA Region IX. Arrival time is 0800.
2. Since the test equipment was already setup from previous testing for EPA-OAQPS, all that had to be done was charging of the impinger train and laoding of the filter.
3. While the test equipment was being readied, R. Larkin checked the plant for steady-state acid plant operation and the converter's copper blow schedule.
4. SO_2 concentrations existing from the tail gas stack were found to be approximately 1300 ppm — well over the value representative of normal operation. The problem was caused by blower malfunctions. However, the major delay was caused by the copper blow schedule. The next blow was not scheduled until between 1900 and 2000. It was decided not to test today.
5. For the remainder of the day, samples and equipment from the previous week's testing were packed for shipment. In addition, Clint Fitch, Kenncott's Control Supervisor gave the test crew and the Region IX representative a plant tour.

Day No. 2, December 15, 1976

1. Test crew arrives at the plant at 0800.
2. A copper blow is in progress and the acid plant is under steady-state operating conditions — so the first test started at 0919.

3. The test proceeded with no upsets and was completed at 1150. Equipment was returned to the laboratory for sample recovery.

4. The following observations were made regarding the appearance of the samples from Test No. 1:

   - All washes and impinger solutions were clear
   - The filter had a light off-white tinge and no visible particulate

5. The gas sample in the Tedlar bag was analyzed on an Orsat apparatus and gave these results:

   O_2 – 8.3 percent
   SO_2 – 0.2 percent
   CO – 0.0 percent

6. The next copper blow was scheduled for 2000 hours to the crew returned to the motel at 1400 after recharging the train for the next test.

7. We returned to the plant at 1900 and transported the sampling train to the test location. Copper blow had started and the acid plant was operating normally, so Test No. 2 started at 2015.

8. There were no problems during Test No. 2 and upon completion at 2318 the equipment was returned to the lab for sample recovery.

9. We left the plant at approximately 0100 – December 16, 1976.

Day No. 3, December 16, 1976

1. The test crew arrived at the plant at 0930. By 1030 copper blow had started and the acid plant was operating normally so Test No. 3 started at 1048.

2. At 1104 the test was stopped for 13 minutes due to an interruption in the copper blow. During this time, the train was purged with the gas meter reading changing from 968.884 to 969.404. Copper blow and the test continued at 1117.

3. The test was completed at 1335 with no further interruption. The appropriate equipment was returned to the laboratory for

sample recovery while the remainder was packed in the shipping crate.

4. By 1900 all equipment and samples had been apcked for shipment. We left the plant at 1930 and flew home the following day.

APPENDIX B

CALCULATIONS AND DATA SHEETS

HAYDEN , REVERB
PRELIMINARY
8/2/76

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{lc} \left(\frac{\rho H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474\ (77.1)$$

$$= 3.65454\ ft^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ (52.96)\ \left(\frac{28.78 + \frac{2}{13.6}}{565.375}\right)$$

$$= 47.988\ ft^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{3.65454}{3.65454 + 47.988}$$

$$= .07077$$

2. Stack Gas Composition

$$M_d = 0.44\,(\%CO_2) + 0.32\,(\%O_2) + 0.28\,(\%N_2 + \%CO)$$

$$+0.64\,(\%SO_2)$$

$$= 0.44\,(3.9) + 0.32\,(13.07) + 0.28\,(83.03 + 0) + 0.64\,(\quad)$$

$= 29.1468$ lb/lb-mole

$$M_s = M_d\,(1-B_{wo}) + 18\,B_{wo}$$

$$= 29.1468\,(1-.07077) + 18\,(.07077)$$

$= 28.3581$ lb/lb-mole

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

$$= 85.48 \times \underline{\qquad} \times \sqrt{\underline{\qquad\qquad}}$$

$=$ ______ ft/sec

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

2.1 DATE 8/2/76
TIME 5:35 pm
RUN Preliminary

2.2 OPERATORS Gilchrist

2.3 STATIC PRESSURE (IN. HG.)
AMBIENT PRESSURE (IN. HG.) 28.76
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

2.5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)

EOF

2.6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.0	12.3	0.8
3.5	13.4	0.3
4.2	13.5	0.4
Average	Average	Average
3.9	13.07	.5

EOF
EOF

0,0 [PLANT *Kennecott Copper, Hayden Arizona*
LOCATION *Reverb Stack*
0,1 [STACK DIAMETER (IN.) *336*
0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0
1,1 [DATE *8/2/76*
TIME *5:38 pm*
RUN *Preliminary*
1,2 [OPERATORS *Gilchrist*
1,3 [STATIC PRESSURE (IN. HG.)
AMBIENT PRESSURE (IN. HG.) *28.78*
TYPE S PITOT COEFFICIENT *0.771*
1OF

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	480	280	301.0
Initial	350	350	263.9
Liquid Collected	130	−70	17.1
			Total, V_{lc}
			77.1

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
5:38	522.469	2	105	105		287
	526.82	2	105	105		288
	531.35	2	105	105		289
	535.68	2	105	105		287
	540.12	2	106	105		302
	544.545	2	106	105		302
	548.97	2	106	105		301
	553.41	2	106	105		303
	557.85	2	105	105		302
	562.29	2	106	105		302
	566.72	2	106	106		303
	571.13	2	106	106		303
	575.535					

Total, V_m	Average	Avg., T_m
53.066	2	105.3[illegible]

EOF
EOF

+460

$\frac{V_m}{1 . 2}$ = 52.46

= [illegible]

Hayden Run 1

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{1c}$$

$$= 0.0474\ (123.1)$$

$$= 5.835\ \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ \frac{(71.676)}{1.002}\left(\frac{27.87 + \frac{1.5}{13.6}}{92.1 + 460}\right)$$

$$= 64.203\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{5.835}{5.835 + 64.203}$$

$$= 0.0833$$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (9.2) + 0.32\ (13.46) + 0.28\ (81.94 + \overset{0.4}{0}) + 0.64\ (0)$$

$$= 29.21 \text{ lb/lb-mole}$$

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= (29.21)\ (1-0.0833 + 18\ (0.0833)$$

$$= 28.276 \text{ lb/lb-mole}$$

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

/

$$= 85.48 \times 0.784 \times 0.0707 \sqrt{\frac{285.2 + 460}{(27.86)(28.276)}}$$

$$= 4.608 \text{ ft/sec}$$

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1-0.0833)\,(9.606)(615.75)\left(\frac{530}{285.2 + 460}\right)\left(\frac{27.86}{29.92}\right)$$

$$= 6.2017 \times 10^6 \quad \text{scfh}$$

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{1c}$$

$$= 0.0474$$

$$= 5.835\ \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ \cancel{(78.695)}\ 1.025\left(\frac{27.87 + \frac{1.204}{13.6}}{95.48 + 460}\right)$$

$$= 68.437\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{5.835}{5.835 + 68.437}$$

$$= 0.0786$$

5. Concentration of Particulate Matter

	at 0 sec	1st reading	equilibrium
C_s	$= \frac{M}{V_{m,std}}(2.205 \times 10^{-6})$		
	$= \frac{175.96}{68.437}(2.205 \times 10^{-6})$	$\frac{181.55}{68.437}(2.205 \times 10^{-6})$	$\frac{242.21}{68.437}(2.205 \times 10^{-6}$
	$= 5.6693 \times 10^{-6}$ lb/ft³	$= 5.8494 \times 10^{-6}$ lb/ft³	$= 7.8039 \times 10^{-6}$ lb/ft³

6. Emission Rate of Particulate Matter

ER	$= Q_s C_s$		
	$= (6.2017 \times 10^{6})(5.6693 \times 10^{-6})$	$(6.2017 \times 10^{6})(5.8494 \times 10^{-6})$	$(6.2017 \times 10^{6})(7.8039 \times 10^{-6})$
	= 35.1595 lb/hr	= 36.2764 lb/hr.	= 48.3972 lb/hr.

7. **Percent Isokinetic**

$$I = \frac{1.667\ T_s \left\{0.00267\ V_{1c} + \frac{V_m}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6}\right)\right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(745.7) \left\{0.00267\ (123.1) + \frac{76.78}{535.5} \left(27.87 + \frac{1.204}{13.6}\right)\right\}}{(120)\ (4.608)(27.86)(.00307\ \ )}$$

$$= 110.13$$

8. **Concentration of Sulfur Trioxide/Acid Mist**

$$C_{H_2SO_4} = (1.08 \times 10^{-4})\ \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4})\ \frac{(3.3 - .05\ \ )(.01331)\left(\frac{365}{10}\right)}{68.44}$$

$$= 2.484 \times 10^{-6}\ \text{lb/ft}^3$$

9. **Emission Rate of Sulfur Trioxide/Acid Mist**

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 6.2017 \times 10^{6} \cdot 2.484 \times 10^{-6}$$

$$= 15.4\ \text{lb/hr}$$

10. **Concentration of Sulfur Dioxide**

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(10.15 - .05)(.699)\left(\frac{1060}{10}\right)}{68.44}$$

$$= 7.63 \times 10^{-4} \text{ lb/ft}^3$$

11. **Emission Rate of Sulfur Dioxide**

$$ER = Q_s C_{SO_2}$$

$$= 6.2017 \times 10^{6} \times 7.63 \times 10^{-4}$$

$$= 4732 \text{ lb/hr.}$$

0,0 PLANT Kennecott Copper, Haydan Arizona
LOCATION Reverb Stack

0,1 STACK DIAMETER (IN.) 336

0,2 DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 DATE 8/5/76
TIME 10:48 am
RUN 1

1,2 OPERATORS Gilchrist

1,3 STATIC PRESSURE (IN. WG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT

10F

1,4 WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	441	495	463.8
Initial	350	500	426.7
Liquid Collected	91	-5	37.1
			Total, W_w
			123.1

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
10:48	742.554	1.5	88	87		277
10:58	749.710	1.5	90	89		260
11:08	756.85	1.5	91	89		277
11:18	763.96	1.5	92	91		282
11:28	771.045	1.5	93	90		284
11:38	778.335	1.5	93	92		287
11:48	785.470	1.5	94	92		286
11:58	793.51	1.5	94	93		288
12:08	799.655	1.5	95	93		287
12:18	806.935	1.5	96	94		284
12:28	814.23	1.5	96	94		289
12:38						

Total, V_m	Average	Avg., T_m
71.676	1.5	92.1

EOF
EOF

No Punch

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

2,1
DATE 8/5/76
TIME 10:48 am
RUN 1

2,2 OPERATORS Gilchrist

2,3
STATIC PRESSURE (IN. WG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT

STACK GAS MOLECULAR WEIGHT

2,5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
10:48	2		277
10:58	2		261
11:08	2		277
11:18	2		282
11:28	2		284
11:38	2		287
11:48	2		286
11:58	1		288
12:08	1		287
12:18	1		284
12:28	1		289

EOF

2,6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.2	13.4	0.4
4.2	13.5	0.4
4.2	13.5	0.4
Average	Average	Average
4.2	13.46	0.4

EOF
EOF

1/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336.
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 8/5/76
TIME 9:51 am
RUN 1

4.02 OPERATORS Knirck

4.03
STATIC PRESSURE (IN.HG.) -1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.86
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05
METER BOX NUMBER 0039 (B) 0038 (A, C, D)
ORIFICE METER COEFFICIENT 0.695, 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
B-6	9:51	280	255	77	245	85	88	0.0088	2.5	23.22	15
B-5	9.56	280	253	77	250	86	84	0.0088	2.5	27.90	13
B-4	10:01	282	253	77	281	87	84	0.0069	1.5	32.358	12
B-3	10:06	282	251		268	88	85	0.0022	0.5	36.140	5
B-2	10:11	278	259		276	88	82	0.0033	0.7	38.320	5
B-1	10:16	278	259		256	88	86	0.0069	0.4	40.558	4
	10:21									42.400	
A-6	10:55	283	255		285	92	88	0.0027	0.6	84.52	6
A-5	11:00	280	265		260	93	89	0.0027	0.6	87.00	6
A-4	11:05	274	261	88	259	95	91	0.0033	0.7	89.64	7
A-3	11:10	274	262		255	96	92	0.0060	1.3	92.455	9
A-2	11:15	285	262		258	96	93	0.0047	1.0	96.035	8
A-1	11:20	282	261		255	97	94	0.0047	1.0	99.375	8
	11:25									102.600	
		Average				Average	Average		Average	Total	
						Average					

EDV

[illegible]

√DP [illegible] ΔH
[illegible] [illegible] 1.204 [illegible]

B-14

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2/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

DATE 8/5/76
4.01 TIME 11:58 am
RUN 1

4.08 OPERATORS Knirck
STATIC PRESSURE (IN.WG.) −1.3
4.03 AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.86
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

METER BOX NUMBER 0038
4.06 ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
D-6	11:58	292	264	94	254	101	100	0.0038	0.8	110.45	[illegible]7
D-5	12:03	294	267		250	104	100	0.0035	0.8	113.55	[illegible]7
D-4	12:08	291	263	100	254	102	101	0.0018	0.3	116.53	[illegible] 5
D-3	12:13	290	258		257	103	102	0.0013	0.3	118.88	6
D-2	12:18	288	263		258	103	102	0.0013	0.3	121.07	5
D-1	12:23	250	264	100	254	103	102	0.0013	0.3	123.065	5
	12:28									125.475	
C-6	1:01	298	262		273	101	101	0.0235	3.8	125.51	22
C-5	1:06	299	258	90	261	102	101	0.0221	3.8	131.215	22
C-4	1:11	298	261		226	102	101	0.0096	2.0	137.15	10
C-3	1:16	298	264	86	226	102	102	0.0060	1.3	141.72	8
C-2	1:21	298	256	87	245	102	102	0.0033	0.7	145.43	6
C-1	1:26	291	260	88	234	103	102	0.0036	1.2	148.34	7
	1:31									151.72	
		Average				Average	Average		Average	Total	
						Average					

EOF

B-15

Hayden Run 2

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{1c}$$

$$= 0.0474\ (127.4)$$

$$= 6.039\ \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ \frac{(87.409)}{1.002}\left(\frac{27.87 + \frac{1.5}{13.6}}{561.625}\right)$$

$$= 76.968\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{6.039}{6.039 + 76.968}$$

$$= 0.0728$$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

Same as run 1

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (\quad) + 0.32\ (\quad) + 0.28\ (\quad + 0) + 0.64\ (\quad)$$

$$= 29.21 \text{ lb/lb-mole}$$

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= (29.21)\ (1-0.0728) + 18\ (0.0728)$$

$$= 28.394 \text{ lb/lb-mole}$$

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

$$= 85.48 \times 0.784 \times 0.1175 \sqrt{\frac{297.083 + 460}{(27.86)(28.394)}}$$

$$= 7.703 \text{ ft/sec}$$

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1-0.0724)\,(7.703)(615.75)\left(\frac{530}{\underset{+460}{299.08}}\right)\left(\frac{27.56}{29.92}\right)$$

$$= 1.0323 \times 10^{7} \text{ scfh}$$

4. **Stack Gas Moisture Content** (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\, T_{std}}{P_{std}}\right)$$

$$= 0.0474\, V_{1c}$$

$$= 0.0474$$

$$= 6.039 \text{ ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{\cancel{std}}}\right)$$

$$= 17.71\,\left(\frac{114.52}{1.025}\right)\left(\frac{27.87 + \frac{2.517}{13.6}}{\underset{+460}{104.229}}\right)$$

$$= 98.385 \text{ ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{6.039}{6.039 + 98.385}$$

$$= 0.0578$$

5. Concentration of Particulate Matter

$$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$$

at 0 sec	1st reading	equilibrium
$= \frac{249.49}{98.385} (2.205 \times 10^{-6})$	$\frac{251.64}{98.385} (2.205 \times 10^{-6})$	$\frac{316.49}{98.385} (2.205 \times 10^{-6})$
$= 5.5916 \times 10^{-6}$ lb/ft³	$= 5.6397 \times 10^{-6}$ lb/ft³	$= 7.0932 \times 10^{-6}$

6. Emission Rate of Particulate Matter

$$ER = Q_s C_s$$

$= (1.0323 \times 10^{7})(5.5916 \times 10^{-6})$	$= (1.0323 \times 10^{7})(5.6397 \times 10^{-6})$	$= (1.0323 \times 10^{7})(7.0932 \times 10^{-6})$
$= 57.722$ lb/hr	$= 58.219$ lb/hr	$= 73.223$ lb/hr

7. **Percent Isokinetic**

$$I = \frac{1.667\ T_s \left\{ 0.00267\ V_{1c} + \frac{V_m}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(157.1) \left\{ 0.00267\ (124.4) + \frac{111.73}{544.2} \left(27.87 + \frac{2.517}{13.6} \right) \right\}}{(120)\ (1.703)(27.86)(.00307\quad)}$$

$$= 94.03$$

8. **Concentration of Sulfur Trioxide/Acid Mist**

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb}\right) \left(\underline{N}\right) \left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(4.95 - .05\quad)(.01331)\left(\frac{980}{10}\right)}{98.385}$$

$$= 3.09 \times 10^{-6}\ \text{lb/ft}^3$$

9. **Emission Rate of Sulfur Trioxide/Acid Mist**

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 1.0323 \times 10^{7} \times 3.09 \times 10^{-6}$$

$$= 31.9\ \text{lb/hr}$$

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(12.0 - .05)(.6919)\left(\frac{1010}{10}\right)}{98.385}$$

$$= 5.759 \times 10^{-4}\ \mathrm{lb/ft^3}$$

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$$= 1.0323 \times 10^{7} \times 5.759 \times 10^{-4}$$

$$= 5945\ \mathrm{lb/hr.}$$

0,0 [PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack

0,1 [STACK DIAMETER (IN.) 336

0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 [DATE 8/5/76
TIME 4:35 pm
RUN 2

1,2 [OPERATORS Gilchrist

1,3 [STATIC PRESSURE (IN. HG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

10F

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	429	494	505.3
Initial	350	500	450.9
Liquid Collected	79	-6	54.4
			Total, W_w
			127.4

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
4:35	814.41	1.5	99	99		291
4:45	821.92	1.5	99	99		292
4:55	829.145	1.5	101	100		294
5:05	836.525	1.5	102	101		296
5:15	843.721	1.5	104	103		298
5:25	851.53	1.5	104	103		297
5:35	858.75	1.5	105	104		300
5:45	865.745	1.5	102	102		298
5:55	873.13	1.5	102	102		297
6:05	880.381	1.5	102	102		296
6:15	887.42	1.5	101	101		292
6:25	894.715	1.5	101	101		292
6:35	901.819		[illegible]	[illegible]		

	Total, V_m	Average	Avg., T_m
	87.409		101.6[illegible]

EOF
EOF

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

DATE 8/5/76
TIME 4:35 pm
RUN 2

OPERATORS Gilchrist

STATIC PRESSURE (IN. WG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
4:35	2		291
4:45	2		292
4:55	2		294
5:05	2		296
5:15	2		298
5:45	1		298
5:55	1		297
6:05	1		296
6:15	2		292
6:25	2		292

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
bag leak - use data from Test 1		
Average	Average	Average
4.2	13.5	0.4

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4,01 DATE 8/5/76
TIME 6:39 pm
RUN 2

4,02 OPERATORS Knirck

4,03 STATIC PRESSURE (IN.HG.) -1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.). 27.86
4,07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

METER BOX NUMBER 0038
4,05 ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75 .0031

PARTICULATE SAMPLING DATA

4,08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-6	6:39	303	253		236	102	102	0.0235	3.9	119.93	
A-5	6:44	304	257		245	103	102	0.0235	3.9	125.94	
A-4	6:49	300	257		244	103	102	0.0276	3.9	131.89	
A-3	6:54	290	254		245	104	103	0.0276	4.0	137.50	
A-2	6:59	293	254		244	106	103	0.0207	4.0	143.14	
A-1	7:04	274	246		246	107	103	0.0179	4.1	149.22	
	7:09									155.37	
B-6	7:51	303	258		244	101	102	0.0044	1.1	155.57	
B-5	7:56	304	254		246	101	101	0.0055	1.2	158.70	
B-4	8:01	300	255		244	101	101	0.0044	0.9	162.57	
B-3	8:06	294	258		244	101	101	0.0033	0.7	165.80	
B-2	8:11	293	249		254	101	101	0.0033	0.7	168.76	
B-1	8:16	278	248		250	101	101	0.0022	0.5	171.68	
	8:21									174.28	
		Average				Average Average	Average		Average	Total	

EOF

$\overline{\sqrt{\Delta P}}$ avg DH V_m

10.9 [illegible]

PLANT Kennecott Copper, Haydem Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01 DATE 8/5/76
TIME 4:36 pm
RUN 2

4.02 OPERATORS Knirck

4.03 STATIC PRESSURE (IN.HG.) -1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.86

4.07 MOLECULAR WEIGHT (LB/LB-MOLE)

B_{wo}

4.05 METER BOX NUMBER 003B
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
C-6	4:36	300	258		236	105	105	0.0[illegible]	2.8	59.41	24
C-5	4:41	300	255		240	105	105	0.0179	2.7	65.73	24
C-4	4:46	301	250		249	106	106	0.0152	2.7	70.74	24
C-3	4:51	300	258	102	249	108	106	0.0124	2.7	75.75	24
C-2	4:56	300	254		245	107	106	0.0069	1.5	80.83	11
C-1	5:01	294	254		247	107	107	0.0074	1.6	84.76	11
	5:06									88.66	
D-6	5:40	303	248		255	107	106	0.0207	2.7	88.66	24
D-5	5:45	305	249		242	110	107	0.0221	3.0	93.72	24
D-4	5:50	306	251		230	108	108	0.0193	3.1	98.87	24
D-3	5:55	304	255		261	103	106	0.0221	3.0	104.15	24
D-2	6:00	297	247		245	105	106	0.0193	2.8	109.40	24
D-1	6:05	284	254		245	105	106	0.0166	3.0	114.50	24
	6:10									119.78	
		Average				Average	Average		Average	Total	
						Average					

EOF

Hayden Run 3

1. Stack Gas Moisture Content (Moisture Train Data)

$$V_{w,std} = V_{1c} \left(\frac{\rho\, H_2O}{M_{H_2O}}\right) \left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{1c}$$

$$= 0.0474\ (175.0)$$

$$= 8.295\ \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right) \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ \frac{(80.249)}{1.002} \left(\frac{27.87 + \frac{1.5}{13.6}}{98.75 + 460}\right)$$

$$= 71.027\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{8.295}{8.295 + 71.027}$$

$$= 0.1046$$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

0A

$$= 0.44\ (3.73) + 0.32\ (13.76) + 0.28\ (82.11 + 0) + 0.64\ (\ 0\ )$$

= 29.147 lb/lb-mole

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= 29.147\ (1-0.1046) + 18\ (0.1046)$$

= 27.981 lb/lb-mole

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

/

$$= 85.48 \times 0.784 \times (0.04514) \sqrt{\frac{288.956 + 460}{(27.86)(27.981)}}$$

= 29.65 ft/sec

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A\left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1 - \underset{.8956}{0.1046})\,(2.965)\,(615.75)\left(\frac{530}{\underset{+460}{288.958}}\right)\left(\frac{27.86}{29.92}\right)$$

$$= 3.8787 \times 10^6 \text{ scfh}$$

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\,H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{1c}$$

$$= 0.0474$$

$$= 8.295 \text{ ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\,\frac{(56.328)}{1.225}\left(\frac{27.87 + \frac{0.475}{13.6}}{105.646 + 460}\right)$$

$$= 48.013 \text{ ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{8.295}{8.295 + 48.013}$$

$$= 0.1473$$

5. Concentration of Particulate Matter

at 0' sec	1st reading	equilibrium
$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$		
$= \frac{130.17}{48.013} (2.205 \times 10^{-6})$	$\frac{133.07}{48.013} (2.205 \times 10^{-6})$	$\frac{197.32}{48.013} (2.205 \times 10^{-6})$
$= 5.9781 \times 10^{-6}$ lb/ft^3	$= 6.1112 \times 10^{-6}$	$= 9.0619 \times 10^{-6}$

6. Emission Rate of Particulate Matter

$ER = Q_s C_s$		
$= (3.8787 \times 10^{6})($	$= (3.8787 \times 10^{6})(6.1112 \times 10^{-6})$	$= (3.8787 \times 10^{6})(4.0619 \times 10^{-6})$
$= 23.1871$ lb/hr	$= 23.7037$ lb/hr	$= 35.1485$ lb/hr

7. **Percent Isokinetic**

$$I = \frac{1.667\ T_s \left\{ 0.00267\ V_{1c} + \frac{V_m}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right\}}{\theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(749) \left\{ 0.00267\ (115\ ) + \frac{54.96}{565.6} \left(27.87 + \frac{.475}{13.6} \right) \right\}}{(120)\ (2.965)(27.86)(.00307\ \ )}$$

$$= 130.4$$

8. **Concentration of Sulfur Trioxide/Acid Mist**

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb}\right) \left(\underline{N}\right) \left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(0 - .05\ \ )(.01331)\left(\frac{640}{10}\right)}{40.01}$$

$$= -9.581 \times 10^{-8}\ lb/ft^3$$

9. **Emission Rate of Sulfur Trioxide/Acid Mist**

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 3.8787 \times 10^{6} \times -9.581 \times 10^{-8}$$

$$= -.372\ lb/hr$$

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(4.85 - .05)(.6919)\left(\frac{1050}{10}\right)}{48.01}$$

$= .000512$ lb/ft^3

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$= 3.8787 \times 10^6 \times .000512$

$= 1986$ lb/hr.

0,0 PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack

0,1 STACK DIAMETER (IN.) 336

0,2 DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 DATE 8/6/76
TIME 11:44 am
RUN 3

1,2 OPERATORS Gilchrist

IOF

1,3 STATIC PRESSURE (IN. HG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

1,4 WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	496	500	482.5
Initial	350	500	455.5
Liquid Collected	148	0	27.0
			Total, W_w
			175.0

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
11.44	901.985	1.5	95	94		287
11:54	909.48	1.5	97	95		276
12.04	916.745	1.5	98	96		275
12:14	924.04	1.5	99	97		287
12:24	932.04	1.5	100	97		289
12:34	938.383	1.5	101	98		289
12:44	945.877	1.5	100	98		286
1:00	945.97	1.5	100	99		294
1:10	953.291	1.5	100	99		295
1:20	960.60	1.5	100	99		295
1:30	967.766	1.5	102	101		296
1.40	975.00	1.5	103	102		297
1:50	982.234					
	Total, V_m	Average	Avg., T_m			
	[illegible]		[illegible]			

EOF
EOF

No Punch
PLANT Kennecott Copper, Haydon Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

2,1
DATE 8/6/76
TIME 11:44 am
RUN 3

2,2 OPERATORS Gilchrist

2,3
STATIC PRESSURE (IN. WG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

2.5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
11:44	1		287
11:54	1		276
12:04	1		273
12:14	2		287
12:24	2		289
12:34	2		289
12:44	2		286
1:00	2		294
1:10	2		295
1:20	2		295
1:30	2		296
1:40	2		296
1:50			

EOF

2,6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
3.7	13.7	0.4
3.7	13.8	0.4
3.8	13.8	0.4
Average	Average	Average
3.73	13.76	0.4

EOF
EOF

1/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 8/6/76
TIME 11:47 am
RUN 3

4.02 OPERATORS Knirck

4.03
STATIC PRESSURE (IN.HG.) −1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.86
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05
METER BOX NUMBER 0038
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) 0.75 00301

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
C-1	11:47	260	252		238	100	98	0.0011	0.2	79.330	5
C-2	11:52	277	258		262	101	99	0.0019	0.4	81.235	6
C-3	11:57	273	251	84	232	101	100	0.0019	0.4	83.475	6
C-4	12:02	279	255	95	248	102	101	0.0033	0.7	85.825	7
C-5	12:07	291	249	97	246	103	101	0.0038	0.8	88.480	8
C-6	12:12	293	250	98	248	104	102	0.0038	0.8	91.420	8
	12:17									94.440	
D-1	12:45	259	257		254	107	106	0.0005	0.1	94.560	5
D-2	12:50	271	251		235	108	106	0.0019	0.4	96.065	6
D-3	12:55	290	250		258	108	107	0.0027	0.6	98.115	7
D-4	1:00	285	256		245	109	107	0.0013	0.3	100.775	5
D-5	1:05	291	261		243	108	107	0.0033	0.7	102.910	7
D-6	1:10	299	257		250	109	107	0.0038	0.8	105.655	8
	1:15									108.690	
		Average				Average	Average		Average	Total	
						Average					

$\sqrt{\Delta P}$ 3.3 ΔH V

2/a

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 236
DUCT DIMENSIONS (IN.) x (IN.)

4.01 DATE 8/6/76
TIME 2:02 pm
RUN 3

4.02 OPERATORS Knirck

4.03 STATIC PRESSURE (IN.HG.) −1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.86
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.06 METER BOX NUMBER 0038
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-1	2:02	280	257		233	106	106	0.0005	0.1	808.797	4
A-2	2:07	287	262	98	238	106	106	0.0008	0.2	810.710	4
A-3	2:12	290	253		241	106	106	0.0005	0.1	812.325	4
A-4	2:17	298	260		246	106	106	0.0011	0.2	813.830	5
A-5	2:22	300	256		246	106	106	0.0027	0.6	815.600	6
A-6	2:27	302	254		245	106	106	0.0033	0.7	817.840	6
	2:32									820.650	
B-1	3:10	280	254		240	108	107	0.0011	0.2	820.755	5
B-2	3:15	293	258		247	108	107	0.0016	0.4	822.783	6
B-3	3.20	303	262		248	109	108	0.0022	0.5	824.952	6
B-4	3.25	304	254		245	109	108	0.0027	0.6	827.478	6
B-5	3.30	305	255		246	109	108	0.0033	0.7	830.232	6
B-6	3.35	305	258		246	109	108	0.0041	0.9	834.876	7
	3.40									835.990	
		Average				Average Average	Average		Average	Total	

EOF

Run 4
Reverb - Hayden

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{lc} \left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\, T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474 \times 151.7$$

$$= 7.19\ \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{\cancel{T_{std}}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{\cancel{std}}}\right)$$

$$= 17.71\ (85.84) \left(\frac{27.81 + \frac{1.5}{13.6}}{549.25}\right)$$

$$= 77.28\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{7.19}{7.19 + 77.28}$$

$$= .085$$

$100 - (4.3 + 13.6 + .23) = N_2$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 \cancel{+ \%CO})$$

$$\cancel{+0.64\ (\%SO_2)}$$

$$= 0.44\ (4.3) + 0.32\ (13.6) + 0.28\ (81.87 + \overset{.23}{\cancel{0}}) + 0.64\ \cancel{(\quad)}$$

$$= 29.23 \text{ lb/lb-mole}$$

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= 29.23\ (1-.085) + 18\ (.085)$$

$$= 28.28 \text{ lb/lb-mole}$$

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_pC_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_sM_s}}$$

/

$$= 85.48 \times .784 \times .058 \sqrt{\frac{747.9}{27.71\ \ 28.28}}$$

$$= 3.80 \text{ ft/sec}$$

$$Q_s = 3600\ (1 - B_{wo})\ V_{s,avg}\ A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\ (1-.085)\ (3.80)(65.8)\left(\frac{530}{747.9}\right)\left(\frac{27.81}{29.92}\right)$$

$= 5077134$ scfh

4. Stack Gas Moisture Content (Particulate Train Data)

~~$V_{w,std} = V_{1c}\left(\frac{\rho\ H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$~~

~~$= 0.0474\ V_{1c}$~~

~~$= 0.0474$~~

~~$=$ ft³~~

$$V_{m,std} = V_m\left(\frac{T_{\cancel{std}}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{\cancel{std}}}\right)$$

$$= 17.71\ \left(\frac{60.793}{1.025}\right)\left(\frac{27.81+\frac{63.7}{13.6}}{554.95}\right)$$

$= 61.50$ ft³

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$=$

$=$

5. Concentration of Particulate Matter

at 0 sec	1st reading	equilibrium
$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$		
$= \frac{83.70}{61.5} (2.205 \times 10^{-6})$	$\frac{84.17}{61.5} (2.205 \times 10^{-6})$	$\frac{88.64}{61.5} (2.205 \times 10^{-6})$
$= 3.00 \times 10^{-6}$ lb/ft³	$= 3.02 \times 10^{-6}$	$= 3.18 \times 10^{-6}$

6. Emission Rate of Particulate Matter

$ER = Q_s C_s$		
$= (5077134)(3.00 \times 10^{-6})$	$= (5077134)(3.02 \times 10^{-6})$	$= (5077134)(3.18 \times 10^{-6})$
$= 15.24$ lb/hr	$= 15.32$	$\doteq 16.14$

7. Percent Isokinetic

$$I = \frac{1.667\ T_s \left\{ 0.00267\ V_{1c} + \frac{V_m}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right\}}{\theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(747.9) \left\{ 0.00267\ (151.7) + \frac{59.31}{554.95} \left(27.81 + \frac{.637}{13.6} \right) \right\}}{(120)\ (3.80)(22.71)(.00306)}$$

$$= 109.1$$

8. Concentration of Sulfur Trioxide/Acid Mist

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb} \right) \left(\underline{N} \right) \left(\frac{V_{soln}}{V_a} \right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(4.30 - .05)(.01331)\left(\frac{715}{25} \right)}{61.5}$$

$$= 2.84 \times 10^{-6}\ lb/ft^3$$

9. Emission Rate of Sulfur Trioxide/Acid Mist

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 5077134 * 2.84 \times 10^{-6}$$

$$= 14.42\ lb/hr$$

10. **Concentration of Sulfur Dioxide**

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(635 - .05)(.6919)\left(\frac{1085}{10}\right)}{61.5}$$

$$= 5.42 \times 10^{-4} \text{ lb/ft}^3$$

11. **Emission Rate of Sulfur Dioxide**

$$ER = Q_s C_{SO_2}$$

$$= 5077134 * 5.42 \times 10^{-4}$$

$$= 2752.62 \text{ lb/hr.}$$

0,0 [PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb stack

0,1 [STACK DIAMETER (IN.) 336

0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 [DATE 8/9/76
TIME 9:52 am
RUN 4

1,2 [OPERATORS Gilchrist

1,3 [STATIC PRESSURE (IN. WG.)
AMBIENT PRESSURE (IN. HG.) 27.81
TYPE S PITOT COEFFICIENT

10F

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	475	495	489.3
Initial	350	500	457.6
Liquid Collected	125	-5	31.7
			Total, V_{lc}
			151.7

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
9:52	986.956	1.6	87	85		265
10:02	994.185	1.5	88	86		260
10:12	001.315	1.5	89	86		286
10:22	008.520	1.5	90	87		288
10:32	015.952	1.5	90	88		284
10:42	022.853	1.5	90	88		289
10:52	030.286	1.5	90	89		289
11:02	037.235	1.5	90	89		283
11:12	044.430	1.5	91	90		287
11:22	051.590	1.5	92	90		288
11:32	058.710	1.5	92	91		290
11:42	065.832	1.5	93	91		291
11:52	072.973					
	Total, V_m	Average	Avg., T_m			
	56.017	1.5	89.25			

EOF
EOF

549.25

85.94

PLANT *Kennecott Copper, Haydan Arizona*
LOCATION *Reverb Stack*
STACK DIAMETER (IN.) *336*
DUCT DIMENSIONS (IN.) x (IN.)

2.1 DATE *8/9/76*
TIME *9:52 am*
RUN *4*

2.2 OPERATORS *Gilchrist*

2.3 STATIC PRESSURE (IN. HG.)
AMBIENT PRESSURE (IN. HG.) *27.81*
TYPE S PITOT COEFFICIENT *0.771*

STACK GAS MOLECULAR WEIGHT

2.5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
9:52	2.0		285
10:02	2.0		280
10:12	2.0		286
10:22	1.0		288
10:32	1.0		284
10:42	1.0		289
10:52	1.0		289
11:02	1.0		283
11:12	1.0		287
11:22	1.0		288
11:32	1.0		290
11:42	1.0		291

EOF

2.6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.3	13.5	0.2
4.4	13.6	0.2
4.3	13.6	0.3
Average	Average	Average
4.3	13.6	.23

EOF
EOF

2/2

PLANT *Kennecott Copper, Hayden Arizona*
LOCATION *Reverb Stack*
STACK DIAMETER (IN.) *336*
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE *8/9/7*
TIME *12:40 P*
RUN *4*

4.02 OPERATORS *Knirck, Steiner*

4.03
STATIC PRESSURE (IN.HG.) *-1.3*
AMBIENT PRESSURE (IN.HG.) *27.81*
TYPE S PITOT COEFFICIENT *0.784*

STACK PRESSURE (IN.HG.) *27.71*
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05
METER BOX NUMBER *0038*
ORIFICE METER COEFFICIENT *0.706*
PROBE LENGTH (FT.) *10*
NOZZLE DIAMETER (IN.) *0.75*

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-1	12:40	272	256		250	97	97	0.0024	0.48	72.756	3
A-2	12:45	290	256		250	97	97	0.0035	0.70	74.647	5
A-3	12:50	290	248	80	250	98	97	0.0030	0.60	77.322	5
A-4	12:55	294	253		250	98	97	0.0002	0.05	80.065	1
A-5	1:00	293	254	87	250	99	98	0.0041	0.80	81.700	6
A-6	1:05	293	255	86	251	99	98	0.0047	0.90	84.490	6
	1:10									87.480	
B-1	1:22	292	240		250	99	99	0.0005	0.11	87.612	2
B-2	1:27	298	258		251	99	99	0.0033	0.65	88.476	5
B-3	1:32	301	260		249	100	99	0.0033	0.65	90.975	5.5
B-4	1:37	303	246	86	250	100	99	0.0038	0.76	93.770	5.5
B-5	1:42	304	255	89	254	101	100	0.0044	0.87	96.631	6
B-6	1:47	302	258	91	252	101	100	0.0035	0.70	99.639	5.5
	1:52									102.487	
		T_s Average				T_m Average	Average		Average	Total	
		287.9				554.95		.058	[illegible]	60.793	

·747.9

1/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01 DATE 8/9/76
TIME 10:57 am
RUN 4

4.02 OPERATORS Knirck

4.03 STATIC PRESSURE (IN.HG.) -1.3
AMBIENT PRESSURE (IN.HG.) 27.81
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.71
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05 METER BOX NUMBER 0038
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
C-1	10:57	282	257		245	87	87	0.0013	0.27	41.270	2
C-2	11:02	262	257		244	88	88	0.0022	0.43	42.920	3
C-3	11:07	285	258	76	248	89	88	0.0033	0.65	44.995	5
C-4	11:12	290	260	79	249	89	88	0.0038	0.75	47.532	5
C-5	11.17	291	253	80	249	90	89	0.0041	0.80	50.340	6
C-6	11:22	292	260	80	249	90	90	0.0038	0.75	53.300	5
	11:27									56.197	
D-1	11:57	234	246		246	93	92	0.0013	0.27	56.335	2
D-2	12:02	275	245		247	94	93	0.0027	0.55	57.770	4
D-3	12:07	279	247	80	248	94	93	0.0041	0.80	60.232	6
D-4	12:12	286	256	81	249	95	94	0.0044	0.85	63.162	6
D-5	12:17	289	250	85	250	95	94	0.0049	1.00	66.240	6
D-6	12:22	292	256	86	249	95	94	0.0047	0.90	69.500	6
	12:27									72.602	
		Average				Average	Average		Average	Total	
						Average					

EOF

Run 5
Revit stack - Hayden

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{lc} \left(\frac{\rho H_2O}{M_{H_2O}}\right) \left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474 \times 156.1$$

$$= 7.4\ \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right) \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ (86.94) \left(\frac{27.81 + \frac{1.5}{13.6}}{560}\right)$$

$$= 76.77\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{7.4}{76.77 + 7.4}$$

$$= .088$$

$100 - (4.26 + 13.5 + 5.7)$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (4.29) + 0.32\ (13.5) + 0.28\ (76.54 + \overset{5.7}{0}) + 0.64\ (0)$$

$$= 29.22 \text{ lb/lb-mole}$$

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= 29.22\ (1-.088) + 18\ (.088)$$

$$= 28.23 \text{ lb/lb-mole}$$

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

/

$$= 85.48 \times .764 \times .0485 . \sqrt{\frac{750.4}{27.71 \times 28.23}}$$

$$= 3.19 \text{ ft/sec}$$

$$Q_s = 3600\ (1 - B_{wo})\ V_{s,avg}\ A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\ (1 - .0863)\ (3.18)(615.8) \left(\frac{530}{750.4}\right) \left(\frac{27.71}{29.92}\right)$$

$$= 4{,}204{,}160 \text{ scfh}$$

4. **Stack Gas Moisture Content** (Particulate Train Data)

$$V_{w,std} = V_{lc} \left(\frac{\rho\ H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{\cancel{std}}}{P_{\cancel{std}}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474$$

$$= \quad \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{\cancel{std}}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{\cancel{std}}}\right)$$

$$= 17.71\ (50.6) \left(\frac{27.81 + \frac{.505}{13.6}}{560.2}\right)$$

$$= 44.55 \text{ ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$=$

$=$

5. Concentration of Particulate Matter

at 0 sec	1st reading	equilibrium
$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$		
$= \frac{61.11}{44.55} (2.205 \times 10^{-6})$	$\frac{61.53}{44.55} (2.205 \times 10^{-6})$	$\frac{63.31}{44.55} (2.205 \times 10^{-6})$
$= 3.0246 \times 10^{-6}$ lb/ft³	$= 3.0454 \times 10^{-6}$ lb/ft³	$= 3.1335 \times 10^{-6}$ lb/ft³

6. Emission Rate of Particulate Matter

$ER = Q_s C_s$		
$= (4204160)(3.0246 \times 10^{-6})$	$(4204160)(3.0454 \times 10^{-6})$	$(4204160)(3.1335 \times 10^{-6})$
$= 12.7161$ lb/hr	$= 12.8035$ lb/hr	$= 13.1738$ lb/hr

7. Percent Isokinetic

$$I = \frac{1.667\ T_s \left\{0.00267\ V_{1c} + \frac{V_m}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(750.5)\left\{0.00267\ (7.4) + \frac{50.6}{560.2}\left(27.81 + \frac{.505}{13.6}\right)\right\}}{(120)\ (3.1\text{[illegible]})(27.71)(.00307)}$$

$$= 97.69$$

8. Concentration of Sulfur Trioxide/Acid Mist

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb}\right)\left(N\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(3.95 - .05)(.01331)\left(\frac{540}{25}\right)}{44.55}$$

$$= 2.718 \times 10^{-6}\ \text{lb/ft}^3$$

9. Emission Rate of Sulfur Trioxide/Acid Mist

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 4204160 \times 2.718 \times 10^{-6}$$

$$= 11.43\ \text{lb/hr}$$

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(5.60 - .05)(.6919)\left(\frac{1035}{10}\right)}{44.55}$$

$$= .000628 \text{ lb/ft}^3$$

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$$= 4204160 \times .000628$$

$$= 2642 \text{ lb/hr.}$$

0,0 [PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack

0,1 [STACK DIAMETER (IN.) 336

0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 [DATE 8/9/76
TIME 3:40
RUN 5

1,2 [OPERATORS Gilchrist

1,3 [STATIC PRESSURE (IN. HG.)
AMBIENT PRESSURE (IN. HG.) 27.81
TYPE S PITOT COEFFICIENT 0.771

10F

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	474	498	463.2
Initial	350	500	429.1
Liquid Collected	124	-2	34.1
			Total, $V_{\ell c}$
			156.1

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
3:40	73.113	1.5	100	101		295
3:50	80.400	1.5	102	102		297
4:00	87.665	1.5	101	101		297
4:10	95.320	1.5	100	101		300
4:20	102.210	1.5	100	101		300
4:30	109.465	1.5	99	101		302
4:40	116.755	1.5	98	100		291
4:50	124.048	1.5	98	100		293
5:00	131.899	1.5	98	99		292
5:10	139.015	1.5	99	100		293
5:20	145.775	1.5	100	100		292
5:30	152.997	1.5	100	100		290
5:40	160.229					
	Total, V_m	Average	Avg., T_m			
	87.116	1.5	100			

EOF
EOF

86.44 560

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 326
DUCT DIMENSIONS (IN.) x (IN.)

2.1 DATE 8/9/76
TIME 3:40 pm
RUN 5
2.2 OPERATORS Gilchrist
2.3 STATIC PRESSURE (IN. HG.)
AMBIENT PRESSURE (IN. HG.) 27.81
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

2.5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
3:40	2.0		295
3:50	2.0		297
4:00	2.0		297
4:10	2.0		300
4:20	2.0		300
4:30	2.0		302
4:40	2.0		291
4:50	2.0		293
5:00	2.0		292
5:10	2.0		293
5:20	2.0		292
5:30	2.0		290
5:40			

EOF

2.6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.3	13.6	0.5
4.3	13.5	0.6
4.4	13.4	0.6
Average	Average	Average
4.26	13.5	5.7

EOF
EOF

1/2

PLANT Kennecott Copper, Haydon Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 8/9/76
TIME 3:40 pm
RUN 5

4.02 OPERATORS Kairck
4.03
STATIC PRESSURE (IN.WG.) -1.3
AMBIENT PRESSURE (IN.HG.) 27.81
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.71
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05
METER BOX NUMBER 0038
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
C-1	3:40	288	249		249	102	102	0.0008	0.16	9.075	1
C-2	3:45	298	248		233	101	102	0.0016	0.30	10.236	2
C-3	3:50	300	246	90	255	101	102	0.0022	0.43	11.982	2
C-4	3:55	302	250	91	246	101	101	0.0024	0.50	13.840	3
C-5	4:00	302	250	92	250	101	102	0.0035	0.70	16.290	4
C-6	4:05	302	246	91	249	101	101	0.0035	0.70	19.075	4
	4:10									21.935	2.86
D-1	4:25	242	256		230	97	99	0.0013	0.27	22.060	2
D-2	4:40	272	246		249	97	98	0.0022	0.43	23.462	2
D-3	4:45	290	245		249	96	97	0.0033	0.65	25.482	4
D-4	4:50	295	245		248	97	97	0.0041	0.80	28.160	4
D-5	4:55	297	245	92	253	98	97	0.0041	0.80	31.160	5
D-6	5:00	297	252	92	248	98	98	0.0044	0.90	34.137	5
	5:05									37.215	
		Average 290.1				Average	Average		Average .505	Total	
						Average 100.2					

750.4

560.2

.0017 .505 5.96

EOF

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4,01 **DATE** 8/9/76
TIME 5:44 pm
RUN 5

4,02 **OPERATORS** Knirck

4,03 **STATIC PRESSURE (IN.WG.)** -1.3
AMBIENT PRESSURE (IN.HG.) 27.81
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.) 27.71
4,07 **MOLECULAR WEIGHT (LB/LB-MOLE)**
B_{wo}

4,06 **METER BOX NUMBER** OC38
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4,08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-1	5:44	278	246		245	100	100	0.0008	0.16	44.64	2
A-2	5:49	280	252		249	101	101	0.0011	0.22	45.82	2
A-3	5:54	280	249		250	101	101	0.0011	0.22	47.204	2
A-4	5:59	285	253		251	101	101	0.0008	0.16	48.695	2
A-5	6:04	285	253	90	263	100	100	0.0030	0.60	49.830	4
A-6	6:09	286	257	91	252	100	100	0.0030	0.65	52.333	4
	6:14									55.005	[illegible]
B-1	6:35	277	248		248	100	100	0.0008	0.16	55.210	2
B-2	6:40	293	253		249	101	100	0.0022	0.43	56.446	3
B-3	6:45	303	247		250	102	101	0.0030	0.60	58.4[illegible]	4
B-4	6:50	303	257		250	102	101	0.0035	0.70	60.948	5
B-5	6:55	304	248	92	250	103	101	0.0038	0.75	63.842	5
B-6	7:00	304	248	92	250	103	101	0.0041	0.80	66.742	6
	7:05									68.700	[illegible]
		Average			Average	Average	Average		Average	Total	

EOF

Hayden Reverb　　Run 6

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{1c} \left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\; T_{std}}{P_{std}}\right)$$

$$= 0.0474\, V_{1c}$$

$$= 0.0474(145.6)$$

$$= 6.901 \text{ ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ (87.059) \left(\frac{27.87 + \frac{1.5}{13.6}}{97.708 + 460}\right)$$

$$= 77.346 \text{ ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{6.901}{6.901 + 77.346}$$

$$= 0.08191$$

$100 - (4.27 + 13.9 + 0)$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 \cancel{+ \%CO})$$

$$\cancel{+0.64\ (\%SO_2)}$$

$$= 0.44\ (4.27) + 0.32\ (13.9) + 0.28\ (81.83 + 0) + \cancel{0.64\ (}\quad)$$

$= 29.24$ lb/lb-mole

$$M_s = M_d\ (1 - B_{wo}) + 18\ B_{wo}$$

$$= 29.24\ (1 - .0819) + 18\ (.0819)$$

$= 28.32$ lb/lb-mole

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

$$= 85.48 \times .811 \times .0537 \sqrt{\frac{748.4}{27.77 \times 28.32}}$$

$= 3.63$ ft/sec

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1-.1819)\,(3.63)(615.70\left(\frac{530}{748.4}\right)\left(\frac{27.77}{29.92}\right)$$

$$= 4{,}855{,}869 \text{ scfh}$$

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\,H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{1c}$$

$$= 0.0474$$

$$= \qquad \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\,(55.44)\left(\frac{27.87 + \frac{0.86}{13.6}}{\frac{95.7 + 460}{555.7}}\right)$$

$$= 49.35 \text{ ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

=

=

5. Concentration of Particulate Matter

at 0 sec	1st reading	equilib.
$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$		
$= \frac{81.25}{49.35} (2.205 \times 10^{-6})$	$\frac{91.12}{49.35} (2.205 \times 10^{-6})$	$\frac{102.45}{49.35} (2.205 \times 10^{-6})$
$= 3.8984 \times 10^{-6}$ lb/ft³	$= 4.0713 \times 10^{-6}$	$= 4.5776 \times 10^{-6}$

6. Emission Rate of Particulate Matter

$ER = Q_s C_s$		
$= (4855869)(3.8984 \times 10^{-6})$	$(4855869)(4.0713 \times 10^{-6})$	$(4855864)(4.5776 \times 10^{-6})$
= 18.9301 lb/hr	= 19.7698 lb/hr	= 22.2280 lb/hr

7. **Percent Isokinetic**

$$I = \frac{1.667\ T_s \left\{0.00267\ V_{1c} + \frac{V_m}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(748.4)\left\{0.00267\ (145.6) + \frac{55.44}{555.7}\left(27.87 + \frac{.655}{13.6}\right)\right\}}{(120)\ (3.63)(27.77)(\ .00307)}$$

$$= 106.6$$

8. **Concentration of Sulfur Trioxide/Acid Mist**

$$C_{H_2SO_4} = (1.08 \times 10^{-4})\ \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4})\ \frac{(1.5 - .05\quad)(.01331)\left(\frac{700}{10}\right)}{49.35}$$

$$= 2.958 \times 10^{-6}\ \text{lb/ft}^3$$

9. **Emission Rate of Sulfur Trioxide/Acid Mist**

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 4855869 * 2.958 \times 10^{-6}$$

$$= 14.37\ \text{lb/hr}$$

10. **Concentration of Sulfur Dioxide**

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{(V_t - V_{tb})(N)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(7.20 - .05)(.6919)\left(\frac{1050}{10}\right)}{49.35}$$

$= .000742$ lb/ft^3

11. **Emission Rate of Sulfur Dioxide**

$$ER = Q_s C_{SO_2}$$

$= 4855869 \times .000742$

$= 3603$ lb/hr.

0,0 [PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack

0,1 [STACK DIAMETER (IN.) 336

0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 [DATE 8/10/76
TIME 1:05 pm
RUN 6

1,2 [OPERATORS Gilchrist

1,3 [STATIC PRESSURE (IN. WG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

IOF

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{WO}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	465	498	465.3
Initial	350	500	432.7
Liquid Collected	115	-2	32.6
			Total, W_w
			145.6

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
1:25	160.298	1.5	96	95		299
1:35	167.581	1.5	97	96		300
1:45	174.842	1.5	97	96		299
1:55	182.099	1.5	98	97		294
2:05	189.390	1.5	98	97		303
2:15	196.678	1.5	98	97		310
2:25	203.925	1.5	99	98		303
2:35	211.162	1.5	100	98		304
2:45	218.410	1.5	101	100		306
2:55	225.698	1.5	99	99		305
3:05	232.970	1.5	97	98		306
3:15	240.268	1.5	96	98		304
3:25	247.524	1.5				
3:35						

Total, V_m	Average	Avg., T_m
87.226	1.5	9[illegible]

EOF
EOF

57.[illegible]

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

2.1 DATE 8/10/76
TIME 1:25 pm
RUN 6

2.2 OPERATORS Gilchrist

2.3 STATIC PRESSURE (IN. HG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.87
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

2.5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
1:25	2		299
1:35	2		300
1:45	2		299
1:55	2		294
2:05	2		305
2:15	2		310
2:25	2		303
2:35	2		304
2:45	2		306
2:55	2		305
3:05	2		306
3:15	2		304

EOF

2.6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.3	13.8	0
4.3	13.8	0
4.2	14.0	0
Average	Average	Average
4.27	13.9	0

EOF
EOF

1/2

B Points

PLANT Kennecott Copper, Hayden Arizona

LOCATION Reverb Stack

STACK DIAMETER (IN.) 206

DUCT DIMENSIONS (IN.) X (IN.)

4.01

DATE 8/10/76

TIME 125 pm

RUN 6

4.02 OPERATORS Knick

4.03

STATIC PRESSURE (IN.HG.) -1.3

AMBIENT PRESSURE (IN.HG.) 27.87

TYPE S PITOT COEFFICIENT ~~0.864~~ 0.811

STACK PRESSURE (IN.HG.) 27.77

4.07 MOLECULAR WEIGHT (LB/LB-MOLE)

B_{wo}

4.05

METER BOX NUMBER 0038

ORIFICE METER COEFFICIENT 0.706

PROBE LENGTH (FT.) 10

NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
C-1	1:25	252	246		249	98	98	0.0018	0.27	74.666	2
C-2	1:30	298	254	87	249	98	98	0.0019	0.37	76.154	3
C-3	1:35	302	253	88	249	98	98	0.0033	0.65	77.915	6
C-4	1:40	304	254	90	258	99	99	0.0033	0.65	80.485	6
C-5	1:45	300	246	91	249	99	99	0.0033	0.65	83.311	6
C-6	1:50	300	248	91	249	100	100	0.0033	0.65	85.836	6
	1:55									88.695	
D-1	2:25	287	255		249	100	100	0.0002	0.05	88.750	1
D-2	2:30	260	246		251	101	100	0.0008	0.16	89.540	2
D-3	2:35	305	253	95	251	101	101	0.0013	0.27	90.712	3
D-4	2:40	312	266	94	250	100	102	0.0019	0.38	92.121	3
D-5	2:45	312	256	90	249	98	100	0.0035	0.70	93.912	5
D-6	2:50	309	258	88	250	96	98	0.0030	0.60	96.295	5
	2:55									99.054	
		Average 288.4				Average	Average	.5537	Average	Total	
						Average					

EOF

+ 460

748.4

555.7

1.075 = 5.536

2/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01 DATE 8/10/76
TIME 3:44 pm
RUN 6

4.02 OPERATORS Knirck

4.03 STATIC PRESSURE (IN.HG.) −1.3
AMBIENT PRESSURE (IN.HG.) 27.87
TYPE S PITOT COEFFICIENT 0.784

STACK PRESSURE (IN.HG.)
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

4.05 METER BOX NUMBER 0036
ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.00

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-1	3:44	233	252		250	96	95	0.0016 .3992	0.22	105.816	2
A-2	3:49	296	249		250	95	95	0.0008 .2283	0.16	107.164	2
A-3	3:54	301	255		250	96	95	0.0018 .1340	0.27	108.438	3
A-4	3:59	303	245		251	96	95	0.0018 .3969	0.27	109.780	3
A-5	4:04	306	245		251	96	95	0.0033 .5574	0.65	111.433	5
A-6	4:09	305	246		251	97	96	0.0033 .3574	0.65	114.120	5
	4:13										
B-1	4:40	235	244		252	92	94	0.0041 .2410	0.8	116.910	
B-2	4:45	285	253		246	90	93	0.0055 .3942	1.1	117.056	5
B-3	4:50	306	248		250	90	93	0.0083 .3911	1.6	119.555	6
B-4	4:55	303	246		246	84	89	0.0083 .3911	1.6	122.812	8
B-5	5:00	301	249		246	83	88	0.0077 .3799	1.5	126.740	9
B-6	5:05	299	244		246	82	87	0.0077 .3799	1.5	130.000	9
	5:10									134.600	9
										136.450	
		2911 Average				Average	Average		Average	Total	
						Average					

92 87

B-65

Run 7 8/11/76
Kennecott Copper, Hayden
Location : Reverb

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{lc} \left(\frac{\rho H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474\ (175.5)$$

$$= 8.319\ \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ (86.549)\left(\frac{29.96 + \frac{1.5}{13.6}}{84.458+460}\right)$$

$$= 78.288\ \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$= \frac{8.319}{8.319 + 78.288}$$

= ~~.000111~~ .0960

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (4.22) + 0.32\ (13.6) + 0.28\ (82.17 + 0) + 0.64\ (0)$$

$$= 29.221 \text{ lb/lb-mole}$$

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= 29.221(1-.096) + 18\ (.096)$$

$$= 28.14 \text{ lb/lb-mole}$$

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_pC_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_sM_s}}$$

$$= 85.48 \text{ X } .784 \text{ X } .0466 \sqrt{\frac{2[illegible].375 + 460}{(29.[illegible]8)(28.14)}}$$

$$= 3.02 \text{ ft/sec}$$

$A = \frac{\pi(\text{[illegible]})}{(4)(144)}$

1.5526 NO

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A\left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1-.096)\,(3.02)(615.8)\left(\frac{530}{733.8}\right)\left(\frac{29.82}{29.92}\right)$$

= [illegible]66000 scfh

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{lc}\left(\frac{\rho\,H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{lc}$$

$$= 0.0474$$

= ft³

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\,(\text{[illegible]})\left(\frac{29.48 + \frac{.547}{13.6}}{528.596}\right)$$

= 48.11 ft³

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

=

=

5. Concentration of Particulate Matter

0 sec | 1st reading | equilibrium

$$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$$

$= \frac{211.34}{48.11} (2.205 \times 10^{-6})$ | $\frac{214.61}{48.11} (2.205 \times 10^{-6})$ | $\frac{229.82}{48.11} (2.205 \times 10^{-6})$

$= 9.6862 \times 10^{-6}$ lb/ft³ | $= 9.8361 \times 10^{-6}$ | $= 1.0533 \times 10^{-5}$

6. Emission Rate of Particulate Matter

$$ER = Q_s C_s$$

$= (4066000)(9.6862 \times 10^{-6})$ | $(4066000)(9.8361 \times 10^{-6})$ | $(4066000)(1.0533 \times 10^{-5})$

= 39.3840 lb/hr | = 39.9936 lb/hr | = 42.[illegible] lb/hr

7. **Percent Isokinetic**

$$I = \frac{1.667\ T_s \left\{ 0.00267\ V_{1c} + \frac{V_m}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(7[illegible]4 \left\{ 0.00267\ (175.[illegible]) + \frac{54.185}{558.9} \left(27.98 + \frac{.547}{13.6} \right) \right\}}{(120)\ (3.02)(27.88)(\ .00307\ )}$$

$$= 127.0$$

8. **Concentration of Sulfur Trioxide/Acid Mist**

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb}\right) \left(\underline{N}\right) \left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(.70 - .05\ )(.01331)\left(\frac{550}{10}\right)}{48.11}$$

$$= 1.126 \times 10^{-6}\ lb/ft^3$$

9. **Emission Rate of Sulfur Trioxide/Acid Mist**

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 4066000 \times 1.126 \times 10^{-6}$$

$$= 4.58\ lb/hr$$

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(13.5 - .05)(.1092)\left(\frac{1040}{3}\right)}{48.11}$$

$= .000746$ lb/ft^3

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$= 4066000 \times .000746$

$= 3039$ lb/hr.

0,0 [PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack

0,1 [STACK DIAMETER (IN.) 336

0,2 [DUCT DIMENSIONS (IN.) x (IN.)

1,0

1,1 [DATE 8/11/76
TIME 10:45 am
RUN 7

1,2 [OPERATORS Gilchrist

1,3 [STATIC PRESSURE (IN. HG.) -1.3
AMBIENT PRESSURE (IN. HG.) 27.98
TYPE S PITOT COEFFICIENT 0.771

10F

1,4 [WET BULB TEMP (°F)
DRY BULB TEMP (°F)
MOISTURE (% VOL.)
B_{wo}

STACK GAS MOISTURE (CONDENSATION)

1,5

	Impinger #1 Weight (gm)	Impinger #2 Weight (gm)	Silica Gel Weight (gm)
Final	498	500	452.4
Initial	350	500	424.9
Liquid Collected	148	0	27.5
			Total, W_w
			175.5

EOF

1,6

Clock Time	Dry Gas Meter (ft³)	Rotameter Reading (cfh)	Gas Meter Temp (°F) in	Gas Meter Temp (°F) out	Velocity Head (in. wg.)	Stack Gas Temp (°F)
10:45	247.842	1.5	86	84		280
10:55	254.869	1.5	87	85		282
11:05	262.075	1.5	89	86		275
11:15	269.860	1.5	89	87		278
11:25	276.399	1.5	91	88		284
11:35	283.860	1.5	92	89		277
11:45	291.010	1.5	92	90		274
11:55	298.810	1.5	93	90		277
12:05	305.435	1.5	93	91		277
12:15	312.635	1.5	94	91		277
12:25	319.885	1.5	94	92		279
12:35	327.120	1.5	94	92		278
12:45	334.344					

Total, V_m	Average	Avg., T_m
86.?	1.5	89.45 [illegible]

EOF
EOF

[illegible]

No Punch

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) x (IN.)

2,1 DATE 8/11/76
TIME 10:45 am
RUN 7

2,2 OPERATORS Gilchrist

2,3 STATIC PRESSURE (IN. WG.) −1.3
AMBIENT PRESSURE (IN. HG.) 27.98
TYPE S PITOT COEFFICIENT 0.771

STACK GAS MOLECULAR WEIGHT

2,5

Clock Time	Rotameter Reading (cfh)	Velocity Head (in. wg.)	Stack Gas Temp (°F)
10:45	2		280
10:55	2		282
11:05	2		275
11:15	2		276
11:25	2		284
11:35	2		277
11:45	2		274
11:55	2		277
12:05	2		277
12:15	2		277
12:25	2		279
12:35	2		278

EOF

2,6

CO_2 (% by Vol.)	O_2 (% by Vol.)	CO (% by Vol.)
4.3	13.5	0.3
4.2	13.6	0.3
4.2	13.7	0.4
Average	Average	Average
4.23	13.6	.333

EOF
EOF

1/2

PLANT	Kennecott Copper, Hayden Arizona
LOCATION	Reverb Stack
STACK DIAMETER (IN.)	336
DUCT DIMENSIONS (IN.) X (IN.)	

4.01

DATE	8/11/76
TIME	10:45 am
RUN	7

4.02

OPERATORS	Knirck

4.03

STATIC PRESSURE (IN.HG.)	-1.3
AMBIENT PRESSURE (IN.HG.)	27.98
TYPE S PITOT COEFFICIENT	0.784

4.07

STACK PRESSURE (IN.HG.)	27.88
MOLECULAR WEIGHT (LB/LB-MOLE)	
B_{wo}	

4.05

METER BOX NUMBER	0038
ORIFICE METER COEFFICIENT	0.206
PROBE LENGTH (FT.)	10
NOZZLE DIAMETER (IN.)	0.25

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. Hg.)
C-1	10:45	26[illegible]	253		251	92	91	.0022	.43	45 [illegible]	4
C-2	10 [illegible]	263	254		251	93	92	.0045	.76	47 8[illegible]	5
C-3	10:55	264	247		251	94	92	.0035	.76	[illegible]	5
C-4	11:00	262	255	96	251	95	93	.0045	.76	[illegible]	5
C-5	11:05	263	250	96	249	96	94	.0035	.76	[illegible]	5
C-6	11:10	262	254	96	251	96	94	.0035	.76	61 8[illegible]	5
	11:15										
D-1	11:45	221	248		251	95	94	.0008	.16	61 9[illegible]	4
D-2	11:50	251	247		252	95	95	.0022	.43	63 [illegible]	3
D-3	11:55	271	250		251	95	95	.0045	.76	64 861	5
D-4	12:00	280	255		253	96	96	.0045	.76	67 [illegible]	5
D-5	12:05	283	256		252	96	96	.0041	.80	70 28[illegible]	6
D-6	12:10	282	249		263	97	96	.0033	.65	73 [illegible]	5
	12:15									76 [illegible]	
		Average [illegible]				Average [illegible]	Average [illegible]		Average [illegible]	Total	

+460 [illegible]

+460 [illegible]

B-74

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1/2

PLANT Kennecott Copper, Hayden Arizona
LOCATION Reverb Stack
STACK DIAMETER (IN.) 336
DUCT DIMENSIONS (IN.) X (IN.)

4.01 DATE 8/11/76
TIME 1:02 pm
RUN 7

4.02 OPERATORS Knirck
STATIC PRESSURE (IN.HG.) -1.3
4.03 AMBIENT PRESSURE (IN.HG.) 27.98
TYPE S PITOT COEFFICIENT ~~[illegible]~~ .811

STACK PRESSURE (IN.HG.) 27.86
4.07 MOLECULAR WEIGHT (LB/LB-MOLE)
B_{wo}

METER BOX NUMBER 0038
4.05 ORIFICE METER COEFFICIENT 0.706
PROBE LENGTH (FT.) 10
NOZZLE DIAMETER (IN.) 0.75

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. hg.)
A-1	1:02	242	254		252	98	97	.0005	.10	82.640	2
A-2	1:07	267	246		250	98	97	.0008	.16	82.365	2
A-3	1:12	270	246		251	98	98	.0013	.27	84.610	3
A-4	1:17	282	252		251	99	98	.0022	.43	86.013	4
A-5	1:22	283	250		249	99	98	.0038	.75	88.043	8
A-6	1:27	285	250		251	99	98	.0033	.65	90.[illegible]	7
	1:32									93.615	
B-1	2:00	252	249		256	100	100	.0013	.27	93.73	3
B-2	2:05	258	253		249	100	100	.0019	.38	95.160	3
B-3	2:10	272	255		253	101	100	.0033	.65	98.00	6
B-4	2:15	284	246		252	101	100	.0033	.65	99.675	6
B-5	2:20	288	251	93	251	101	101	.0033	.65	02.436	6
B-6	2:25	300	248	92	252	102	101	.0041	.80	5.275	8
	2:30									1.26	
		Average				Average Average	Average		Average	Total	

EOF

B-75

TAILGAS 1A, B

12-15-76

1. **Stack Gas Moisture Content** (Moisture Train Data)

$$V_{w,std} = V_{1c} \left(\frac{\rho\, H_2O}{M_{H_2O}}\right) \left(\frac{R\, T_{std}}{P_{std}}\right)$$

$$= 0.0474\, V_{1c}$$

$$= 0.0474$$

$$= \qquad \text{ft}^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right) \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71 \; (\qquad) \left(\frac{\qquad \frac{}{13.6}}{}\right)$$

$$= \qquad \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$=$$

$$=$$

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (\quad) + 0.32\ (\quad) + 0.28\ (\quad + 0) + 0.64\ (\quad)$$

$= 28.40$ lb/lb-mole

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= 28.40\ (1- 0\ ) + 18\ (0\ )$$

$= 28\ 40$ lb/lb-mole

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

$$= 85.48 \times .780 \times .5205 \sqrt{\frac{646.1}{28.04 * 28\ 40}}$$

$= 31.26$ ft/sec

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A \left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1 - 0\ )\,(31.26)(50.26 \left(\frac{530}{646.1}\right)\left(\frac{28.04}{29.92}\right)$$

$$= 4{,}348{,}170 \text{ scfh}$$

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\,H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{1c}$$

$$= 0.0474$$

$$= \quad \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{\cancel{T_{std}}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{\cancel{P_{std}}}\right)$$

$$= 17.71\,(52.85\ )\left(\frac{28.05 + \frac{1.009}{13.6}}{517}\right)1.001$$

$$= 50.97 \text{ ft}^3$$

✓

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$=$$

$$=$$

5. Concentration of Particulate Matter

$$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$$

$$= \frac{143.71}{50.97} (2.205 \times 10^{-6})$$

$$= 6.217 \times 10^{-6} \text{ lb/ft}^3$$

6. Emission Rate of Particulate Matter

$$ER = Q_s C_s$$

$$= (4{,}348{,}170)(6.217 \times 10^{-6})$$

$$= 27.03 \text{ lb/hr}$$

7. Percent Isokinetic

✓

$$I = \frac{1.667\ T_s \left\{ 0.00267\ V_{1c} + \frac{V_m \alpha}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(646) \left\{ 0.00267\ (0) + \frac{52.85(1.00)}{517} \left(28.05 + \frac{1.009}{13.6} \right) \right\}}{(96)(31.24)(28.04)(3.41 \times 10^{-4})}$$

$= 108.00$

8. Concentration of Sulfur Trioxide/Acid Mist

$$C_{H_2SO_4} = (1.08 \times 10^{-4}) \frac{\left(V_t - V_{tb}\right)\left(N\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4}) \frac{(0 - .05)(.110)\left(\frac{475}{5}\right)}{50.97}$$

$= 0$ lb/ft^3

9. Emission Rate of Sulfur Trioxide/Acid Mist

$$ER = Q_s\ C_{H_2SO_4}$$

$= 4318170 \times 0$

$= 0$ lb/hr

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{(V_t - V_{tb}) \left(N\right) \left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(17.85 - .05)(.110)\left(\frac{390}{10}\right)}{50.97}$$

$$= .0001056 \text{ lb/ft}^3 = 637.8 \text{ ppm}$$

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$$= 4348170 (.0001056)$$

$$= 459.2 \text{ lb/hr.}$$

0853:
Leak Rate =
(.) ~~.23~~ .. 1')
24

PLANT Kennecott Ray Mines
LOCATION Tailgas Stack
STACK DIAMETER (IN.) 96 - 5026
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 12 15 76
TIME 0919
RUN 1 A

4.02 OPERATORS C Stock, E. Rice

4.03
STATIC PRESSURE (IN.HG.) -.13
AMBIENT PRESSURE (IN.HG.) 28.65
TYPE S PITOT COEFFICIENT 0.840

4.07
STACK PRESSURE (IN.HG.) 28.04
MOLECULAR WEIGHT (LB/LB-MOLE) 28.48
B_{wo}

4.09
METER BOX NUMBER 107
ORIFICE METER COEFFICIENT 3.33
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) .25

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. H₂O)	Orifice Meter (in. H₂O)	Gas Meter Volume (ft.³)	Pump Vacuum (in. Hg.)
1	0919	121	248		248	44	43	.55	1.85	809.600	1.
2	0921	168	249		244	44	43	0.75	2.50	811.195	15
3	0923	144	249		245	44	44	0.75	2.50	812.850	16
4	0925	161	250		250	44	44	0.75	2.50	814.6[illegible]	16
5	0927	170	248		250	45	44	0.75	2.50	816.4[illegible]	16
6	0929	170	249		251	45	44	0.60	2.05	818.265	17
7	0931	142	246		244	45	44	0.50	1.68	820.16[illegible]	16
8	0933	183	248		244	45	43	0.30	1.00	821.66[illegible]	6
9	0935	170	249		251	45	45	0.28	0.95	823.016	6
10	0937	155	248		251	46	45	0.25	0.85	824.290	5
11	0939	135	248		250	46	45	0.55	1.85	825.185	11
12	0941	133	249		250	46	45	0.49	1.5[illegible]	826.305	10
13	0943	150	250		251	47	46	0.20	0.65	828.160	4
14	0945	150	249		252	47	46	0.61	0.86	829.18	2
15	0947	185	248		250	47	46	0.61	0.85	829.905	2
16	0949	189	248		252	48	46	0.68	0.85	830.365	2
17	0951	185	250		251	48	46	0.63	0.85	831.135	2
18	0953	180	250		252	48	47	0.68	0.85	831.730	2
19	0955	180	250		254	49	47	0.07	0.15	836.[illegible]	1
20	0957	149	249		253	49	48	0.05	0.15	836.[illegible]	1
21	0959	251	250		251	50	48	0.60	0.2.	837.200	1
22	1001	292	250		254	50	48	0.08	0.85	838.155	1
23	1003	301	250		253	50	47	0.34	~~[illegible]~~	839.[illegible]	6
24	1005	316	252		254	51	44	0.23	0.75	83[illegible]	5
	1007									862.245	
		Average [illegible]				Average [illegible]	Average [illegible]	.53"	Average [illegible]	Total [illegible]	

K = 3.33

The [illegible] of [illegible] [illegible] until point #15
No.19

56.85 5205 Y 1.009 52.65

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Leak Rate = ~~.000~~ 0.009 cfm
@ 23.5 in Hg

PLANT Kennecott - Ray Mines
LOCATION Tail Gas Stack
STACK DIAMETER (IN.) 76
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 12-15-76
TIME
RUN 1B

4.02 OPERATORS G. Stugley G. Rice
STATIC PRESSURE (IN.HG.) -.14
4.03 AMBIENT PRESSURE (IN.HG.) 25.05
TYPE S PITOT COEFFICIENT .840

STACK PRESSURE (IN.HG.) 25.04
4.07 MOLECULAR WEIGHT (LB/LB-MOLE) 28.10
B_{ws} 0

METER BOX NUMBER 0017
4.05 ORIFICE METER COEFFICIENT 3.33
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) .25

PARTICULATE SAMPLING DATA

4.06

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. Hg.)
1	1102	149	250		249	65	61	0.19	0.65	842.255	5
2	1104	173	251		253	65	61	0.27	0.90	843.185	5
3	1106	192	251		257	65	62	0.25	0.85	844.240	6
4	1108	191	251		256	66	62	0.25	0.85	845.310	5
5	1110	190	249		255	66	62	0.23	0.75	846.405	5
6	1112	187	251		254	66	63	0.20	0.65	847.445	4
7	1114	168	250		254	66	63	0.16	0.55	848.340	7
8	1116	148	250		255	66	63	0.20	0.65	849.145	4
9	1118	160	250		256	69	64	0.16	0.55	850.220	[illegible]
10	1120	185	251		256	67	64	0.17	0.55	851.115	7
11	1122	185	250		253	68	65	0.17	0.55	851.775	7
12	1124	186	250		248	69	65	0.30	1.00	852.840	6
13	1126	186	252		250	69	66	0.30	1.00	853.715	[illegible]
14	1128	180	251		252	70	66	0.23	0.75	855.145	5
15	1130	187	252		250	70	67	0.23	0.75	856.265	5
16	1132	188	252		251	71	67	0.23	0.75	857.210	5
17	1134	188	253		252	71	68	0.23	0.75	858.220	5
18	1136	188	253		252	72	68	0.26	0.85	859.220	5
19	1138	187	251		251	72	69	0.30	1.00	860.270	6
20	1140	188	253		253	73	69	0.35	1.15	861.420	7
21	1142	194	254		252	73	70	0.45	1.50	[illegible]	8
22	1144	213	253		254	74	70	0.50	1.65	863.445	9
23	1146	210	251		252	74	70	0.50	1.65	[illegible]	[illegible]
24	1148	235	253		254	74	71	0.45	1.50	866.905	9
	1150									868.897	
		Average [illegible]				Average [illegible]	Average [illegible]	5156	Average [illegible]	Total [illegible]	

1 - 3.33

EOF

TAIL GAS 2A,B
12-15-76

1. Stack Gas Moisture Content (Moisture Train Data)

$$V_{w,std} = V_{lc}\left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{lc}$$

$$= 0.0474$$

$$= \qquad \text{ft}^3$$

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71\ (\qquad)\left(\frac{\qquad \frac{}{13.6}}{}\right)$$

$$= \qquad \text{ft}^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$=$$

$$=$$

2. Stack Gas Composition

$$M_d = 0.44\,(\%CO_2) + 0.32\,(\%O_2) + 0.28\,(\%N_2 + \%CO)$$

$$+0.64\,(\%SO_2)$$

$$= 0.44\,(\quad) + 0.32\,(\quad) + 0.28\,(\quad + 0) + 0.64\,(\quad)$$

$= 28.40$ lb/lb-mole

$$M_s = M_d\,(1-B_{wo}) + 18\,B_{wo}$$

$$= 28.40\,(1-0\quad) + 18\,(0\quad)$$

$= 28.40$ lb/lb-mole

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

$$= 85.48 \times .780 \times .549 \sqrt{\frac{629}{28.01\,(28.40)}}$$

$= 32.55$ ft/sec

✓

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A\left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1 - 0\ )\,(32.55)(50.26)\left(\frac{530}{629}\right)\left(\frac{28.01}{29.92}\right)$$

$$= 4{,}645{,}717 \text{ scfh}$$

4. Stack Gas Moisture Content (Particulate Train Data)

✓

$$V_{w,std} = V_{1c}\left(\frac{\rho\,H_2O}{M_{H_2O}}\right)\left(\frac{R\,T_{std}}{P_{std}}\right)$$

$$= 0.0474\,V_{1c}$$

$$= 0.0474\ \ 0$$

$$= 0 \text{ ft}^3$$

✓

$$V_{m,std} = V_m\left(\frac{\cancel{T_{std}}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{\cancel{P_{std}}}\right)\alpha$$

$$= 17.71\,(56.78)\left(\frac{28.02 + \frac{1.149}{13.6}}{516.5}\right) * 1.001$$

$$= 56.17 \text{ ft}^3$$

✓

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$=$$

$$= 0$$

5. Concentration of Particulate Matter

$$C_s = \frac{M}{V_{m,std}} (2.205 \times 10^{-6})$$

$$= \frac{82.51}{54.77} (2.205 \times 10^{-6})$$

$$= 3.322 \times 10^{-6} \text{ lb/ft}^3$$

6. Emission Rate of Particulate Matter

$$ER = Q_s C_s$$

$$= 4{,}645{,}117 \times 3.322 \times 10$$

$$= 15.43 \text{ lb/hr}$$

✓

7. Percent Isokinetic

$$I = \frac{1.667\ T_s \left\{0.00267\ V_{lc} + \frac{V_m \gamma}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right\}}{\theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(679)\left\{0.00267\ (0) + \frac{56.78}{516.5}\overset{(1.001)}{\wedge}\left(28.02 + \frac{1.149}{13.6}\right)\right\}}{(.16)\ (32.55)(28.01)(3.41 \times 10^{-4})}$$

$$= 108.65$$

8. Concentration of Sulfur Trioxide/Acid Mist

$$C_{H_2SO_4} = (1.08 \times 10^{-4})\ \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4})\ \frac{(.05 - .05)(.110)\left(\frac{360}{3}\right)}{54.77}$$

$$= 0 \quad lb/ft^3$$

9. Emission Rate of Sulfur Trioxide/Acid Mist

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 4645717\ (0)$$

$$= 0 \quad lb/hr$$

10. **Concentration of Sulfur Dioxide**

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{(V_t - V_{tb})\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(23.0 - .05)(.110)\left(\frac{360}{10}\right)}{54.77}$$

$$= .0001165 \text{ lb/ft}^3 = 703.9 \text{ ppm}$$

11. **Emission Rate of Sulfur Dioxide**

$$ER = Q_s C_{SO_2}$$

$$= 4645717 (.0001165)$$

$$= 541.2 \text{ lb/hr.}$$

2215: Leak Rate = 0.005 @ 23 in. Hg

[illegible]
- PLANT Kennecott - Ray Mines
- LOCATION Tailings Stack
- STACK DIAMETER (IN.) [illegible]
- DUCT DIMENSIONS (IN.) X (IN.)

4.01
- DATE 12-15-76
- TIME
- RUN 2A

4.02
- OPERATORS

4.03
- STATIC PRESSURE (IN.HG.) [illegible]
- AMBIENT PRESSURE (IN.HG.) 28.02
- TYPE S PITOT COEFFICIENT [illegible]

4.07
- STACK PRESSURE (IN.HG.) 28.01
- MOLECULAR WEIGHT (LB/LB-MOLE) 28.40
- B_{wo}

4.05
- METER BOX NUMBER 0017
- ORIFICE METER COEFFICIENT 3.33
- PROBE LENGTH (FT.) 10'
- NOZZLE DIAMETER (IN.) .25

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.) ΔP	Orifice Meter (in. wg.) ΔH	Gas Meter Volume (ft.³) VM	Pump Vacuum (in. Hg)
1	2230	[illegible]	251		[illegible]	56	56	0.60	2.[illegible]	918.868	13
2	2232	[illegible]	[illegible]		[illegible]	56	56	0.85	~~[illegible]~~ [illegible]	920.410	2.3
3	2234	173	[illegible]		[illegible]	56	56	0.90	2.70	922.350	2.5
4	2236	178	251		248	56	56	0.90	2.70	923.220	2.5
5	2238	177	250		250	56	56	0.90	2.75	926.110	2.5
6	2240	178	251		250	56	56	1.15	2.75	928.040	2.5
7	2242	176	250		250	56	57	1.10	2.75	929.430	2.5
8	2244	177	249		251	56	56	[illegible]	2.7	931.850	2.5
9	2246	177	249		251	56	56	~~0.90~~ 0.90	[illegible]	933.750	2.[illegible]
10	2248	176	251		252	56	56	0.55	1.85	935.650	13
11	2250	175	251		252	56	56	0.75	2.50	937.325	18
12	2252	174	251		251	56	56	0.42	1.40	939.100	1.0
13	2254	173	250		253	56	56	0.16	0.55	940.625	4
14	2256	172	251		253	56	56	0.10	0.35	941.615	3
15	2258	171	250		252	56	56	0.07	0.25	942.370	3
16	2300	170	251		253	56	57	0.06	0.20	942.940	2
17	2302	164	252		252	56	56	0.05	0.15	943.440	2
18	2304	168	251		252	56	56	0.07	0.25	943.990	2
19	2306	167	250		252	56	56	0.093	0.30	944.585	3
20	2308	167	252		252	56	57	0.13	0.45	945.170	4
21	2310	167	253		252	56	56	0.14	0.45	946.430	4
22	2312	166	251		251	56	56	0.15	0.50	[illegible]	4
23	2314	165	252		251	56	56	0.17	0.55	[illegible]	4
24	2316	164	253		252	56	56	0.17	0.55	948.990	4
	2318									949.308	
		Average [illegible]				Average	Average 56	.549	Average [illegible]	Total [illegible]	

166.7

56.5

56.5

.549

.446

56.79

B-90

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1855: Leak Rate = 0.015 cfm
@ 23 in. Hg

0 Punch
PLANT Kennecott - Ray Mines
LOCATION Tail Gas Stack
STACK DIAMETER (IN.) 96
DUCT DIMENSIONS (IN.) X (IN.)

4,01
DATE 12 15 76
TIME
RUN 2 5

4,02 OPERATORS C. Stanley, E. Rice

4,03
STATIC PRESSURE (IN.HG.) -.14
AMBIENT PRESSURE (IN.HG.) 28.0
TYPE S PITOT COEFFICIENT .780

4,07
STACK PRESSURE (IN.HG.) 28.01
MOLECULAR WEIGHT (LB/LB-MOLE) 29.48
B_{wo}

4,06
METER BOX NUMBER 0017
ORIFICE METER COEFFICIENT 3.33
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) .25

PARTICULATE SAMPLING DATA

4,08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (Ft.³)	Pump Vacuum (in. hg.)
1	2015	99	250		250	56	57	0.25 5	0.85	52.963	6
2	2017	157	252		252	56	57	0.35 592	1.15	875.175	7
3	2019	160	250		252	56	57	0.37	1.25	879.245	8
4	2021	161	250		250	56	57	0.35 593	1.15	[illegible]	
5	2023	162	250		248	56	57	0.32	1.05	881.875	7
6	2025	162	250		250	56	57	0.32	1.05	883.125	7
7	2027	164	251		241	56	57	0.30 518	1.00	884.360	7
8	2029	165	251		252	56	57	0.27 514	0.90	885.565	6
9	2031	166	250		251	56	57	0.25	0.85	886.700	6
10	2033	167	250		252	56	57	0.25	0.85	887.830	6
11	2035	168	250		250	56	57	0.25	0.85	888.955	7
12	2037	168	250		250	56	57	0.30	1.00	890.255	6
13	2039	169	250		250	56	57	0.27	0.90	891.185	6
14	2041	170	244		249	57	57	0.25	0.85	892.345	2
15	2043	171	244		250	56	56	0.10	0.35	893.455	2
16	2045	170	251		252	56	57	0.08	0.25	894.325	2
17	2047	170	251		252	57	56	0.13	0.45	894.965	4
18	2049	171	251		251	57	57	0.16	0.55	895.730	4
19	2051	172	250		250	57	56	0.18	0.60	896.[illegible]	4
20	2053	173	251		251	57	57	0.24	0.80	897.9[illegible]	5
21	2055	176	251		250	57	57	0.30	1.00	898.525	6
22	2057	182	256		249	57	56	0.32	1.05	899.665	7
23	2059	189	253		253	57	57	0.32	1.05	900.875	7
24	2101	187	252		250	57	57	0.32	1.00	902.105	7
										903.302	
										30.34	
		Average				Average	Average	404	Average	Total	
						Average			96		

K = 3.33

EOF

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TAIL GAS 3A,B
12-16-76

1. Stack Gas Moisture Content (Moisture Train Data)

$$V_{w,std} = V_{1c} \left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\, T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{1c}$$

$$= 0.0474$$

$$= \quad ft^3$$

$$V_{m,std} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)$$

$$= 17.71 \left(\quad\right)\left(\frac{\quad \overline{13.6}}{\quad}\right)$$

$$= \quad ft^3$$

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

=

=

2. Stack Gas Composition

$$M_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$+0.64\ (\%SO_2)$$

$$= 0.44\ (\quad) + 0.32\ (\quad) + 0.28\ (\quad + 0) + 0.64\ (\quad)$$

$= 28.4$ lb/lb-mole

✓

$$M_s = M_d\ (1-B_{wo}) + 18\ B_{wo}$$

$$= \quad (1- \quad) + 18\ (\quad)$$

$= 28.4$ lb/lb-mole

✓

3. Stack Gas Velocity and Flowrate

$$V_{s,avg} = K_p C_p \left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg}}{P_s M_s}}$$

/

$$= 85.48 \times .780 \times .528 \sqrt{\frac{640}{(27.99)(28.4)}}$$

$= 31.59$ ft/sec

✓

$$Q_s = 3600\,(1 - B_{wo})\,V_{s,avg}\,A\left(\frac{T_{std}}{T_{s,avg}}\right)\left(\frac{P_s}{P_{std}}\right)$$

$$= 3600\,(1 - 0\ )\,(31.59)(50.26)\left(\frac{530}{640}\right)\left(\frac{27.99}{29.92}\right)$$

$$= 4{,}428{,}043 \text{ scfh}$$

✓

4. Stack Gas Moisture Content (Particulate Train Data)

$$V_{w,std} = V_{1c}\left(\frac{\rho\, H_2O}{M_{H_2O}}\right)\left(\frac{R\ T_{std}}{P_{std}}\right)$$

$$= 0.0474\ V_{1c}$$

$$= 0.0474$$

$$= 0 \text{ ft}^3$$

✓

$$V_{m,std} = V_m\left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right)\alpha$$

$$= 17.71\,(55.72)\left(\frac{28.00 + \frac{1.001}{13.6}}{530}\right)1.001$$

$$= 52.32 \text{ ft}^3$$

✓

$$B_{wo} = \frac{V_{w,std}}{V_{w,std} + V_{m,std}}$$

$$=$$

$$= 0$$

5. Concentration of Particulate Matter

$$C_s = \frac{M}{V_{m,std}} \; (2.205 \times 10^{-6})$$

$$= \frac{6\text{[illegible]}}{52.32} \; (2.205 \times 10^{-6})$$

$$= 2.636 \times 10^{-6} \text{ lb/ft}^3$$

6. Emission Rate of Particulate Matter

$$ER = Q_s C_s$$

$$= 4428043 * 2.636 \times 10^{-}$$

$$= 11.67 \text{ lb/hr}$$

✓

7. Percent Isokinetic

$$I = \frac{1.667\ T_s \left\{0.00267\ V_{1c} + \frac{V_m}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right\}}{\Theta V_s\ P_s\ A_n}$$

$$= \frac{(1.667)(640)\left\{0.00267\ (0) + \frac{55.72\,(1.001)}{530}\left(28.0 + \frac{1.001}{13.6}\right)\right\}}{(179)(31.59)(27.99)(3.41 \times 10^{-4})}$$

$$= 95.91$$

8. Concentration of Sulfur Trioxide/Acid Mist

$$C_{H_2SO_4} = (1.08 \times 10^{-4})\ \frac{\left(V_t - V_{tb}\right)\left(\underline{N}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (1.08 \times 10^{-4})\ \frac{(.05 - .05)(.110)\left(\frac{360}{3}\right)}{52.32}$$

$$= 0 \quad \text{lb/ft}^3$$

9. Emission Rate of Sulfur Trioxide/Acid Mist

$$ER = Q_s\ C_{H_2SO_4}$$

$$= 4428043\ (0)$$

$$= 0 \quad \text{lb/hr}$$

10. Concentration of Sulfur Dioxide

$$C_{SO_2} = (7.05 \times 10^{-5}) \frac{(V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{V_a}\right)}{V_{m,std}}$$

$$= (7.05 \times 10^{-5}) \frac{(7.65 - .05)(.110)\left(\frac{365}{2}\right)}{52.32}$$

$$= .000206 \text{ lb/ft}^3 = 1242 \text{ ppm}$$

11. Emission Rate of Sulfur Dioxide

$$ER = Q_s C_{SO_2}$$

$$= 4428043 (.000206)$$

$$= 885.6 \text{ lb/hr.}$$

1032 Leak Rate = 0.012 [illegible]
@ 23 in. Hg

4.01 [illegible]
PLANT Kennecott - Ray Mines
LOCATION No. 1 Gas Stack
STACK DIAMETER (IN.) 76 5026
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 12-16-76
TIME
RUN 5A

4.02
OPERATORS C. Shugler, E. Rice

4.03
STATIC PRESSURE (IN.HG.) -.14
AMBIENT PRESSURE (IN.HG.) 28.00 [illegible]
TYPE S PITOT COEFFICIENT .780 Cp

4.07
STACK PRESSURE (IN.HG.) 27.99 P_s
MOLECULAR WEIGHT (LB/LB-MOLE) 28.41
B_{wo} ?

4.05
METER BOX NUMBER 1017
ORIFICE METER COEFFICIENT L - 3.33
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) .25 [illegible]

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F) T_s	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F) T_m	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. H2O) ΔP	Orifice Meter (in. H2O) ΔH	Gas Meter Volume (ft³) V_m	[illegible]
1	1045	[illegible]	254		252	64	62	[illegible]	[illegible]	[illegible]	[illegible]
2	1050	167	252		[illegible]	64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	1052	170	253		[illegible]	64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	1054	171	251		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	1056	171	252		[illegible]	63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	1058	172	253		[illegible]	64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	1100	172	253		[illegible]	64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	1102	172	252		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	1117	[illegible]	252		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	1119	180	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	1121	180	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	1123	181	253		[illegible]	67	61	[illegible]	[illegible]	[illegible]	[illegible]
13	1125	180	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	1127	181	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	1129	182	252		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	1131	182	251		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	1133	183	252		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	1135	183	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	1137	185	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	1139	186	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	1141	181	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	1143	183	254		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	1145	183	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	1147	181	253		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1149									[illegible]	
	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	55.[illegible]	

K = 3.31

[illegible]

1051 Change in flow rate half way through point #2, [illegible] ΔH [illegible]
1104 Test stopped for [illegible] blow, [illegible] ft³. Test stopped during [illegible]
1117 Test restarted at [illegible] ft³ point 9

1222
Leak [illegible] - 0.014 cfm
@24 in. Hg

PLANT Kennecott - Kay Mines
LOCATION Tail Gas Stack
STACK DIAMETER (IN.) 96
DUCT DIMENSIONS (IN.) X (IN.)

4.01
DATE 12-16-76
TIME
RUN 3B

4.02
OPERATORS C. Stanley E. Rice
STATIC PRESSURE (IN.WG.) -.14
4.03
AMBIENT PRESSURE (IN.HG.) 27.00
TYPE S PITOT COEFFICIENT .780

STACK PRESSURE (IN.HG.) 27.[illegible]
4.07
MOLECULAR WEIGHT (LB/LB-MOLE) 28.40
B_{wo} 0

METER BOX NUMBER 5517
4.05
ORIFICE METER COEFFICIENT 3.33
PROBE LENGTH (FT.) 10'
NOZZLE DIAMETER (IN.) .25

PARTICULATE SAMPLING DATA

4.08

Sampling Point Number	Clock Time	Stack Gas Temp (°F)	Probe Temp (°F)	Impinger Outlet Temp (°F)	Oven Temp (°F)	Dry Gas Meter Temp Inlet (°F)	Dry Gas Meter Temp Outlet (°F)	Velocity Head (in. wg.)	Orifice Meter (in. wg.)	Gas Meter Volume (ft.³)	Pump Vacuum (in. Hg.)
1	1247	186	251		253	76	76	0.12 .346	0.40	~~[illegible]~~	3
2	1249	191	250		252	76	75	0.15 .38	0.50	996.155	4
3	1251	186	251		253	75	75	0.15 1	0.50	997.010	4
4	1253	190	252		255	75	75	0.12 .346	0.40	997.900	3
5	1255	190	251		256	74	74	0.12	0.40	998.900	3
6	1257	190	251		255	74	74	0.11 .332	0.35	994.505	5
7	1259	191	252		256	74	74	0.24 .49	0.80	1000.260	5
8	1301	190	251		255	73	74	0.20 .447	0.65	1001.260	4
9	1303	191	251		253	73	74	0.16 .40	0.55	1002.260	4
10	1305	189	252		253	73	74	0.18 .424	0.60	1003.200	4
11	1307	188	252		255	73	74	0.20 .447	0.65	1004.195	4
12	1309	[illegible]	251		256	73	73	0.21 .458	0.70	1005.150	5
13	1311	188	252		254	73	73	0.27 .52	0.90	1006.195	5
14	1313	187	251		252	73	74	0.22 .469	0.75	1007.315	5
15	1315	187	251		254	74	74	0.20 .447	0.65	1008.415	5
16	1317	186	251		255	74	74	0.18 .424	0.60	1009.430	4
17	1319	186	251		254	74	74	0.16 .4	0.60	1010.395	4
18	1321	185	251		253	75	75	0.20 .447	0.65	1011.325	5
19	1323	185	252		254	75	75	0.24 .49	0.80	1012.330	5
20	1325	186	253		256	75	75	0.32 .57	1.05	1013.460	5
21	1327	186	252		254	75	75	0.38 .6	1.25	1014.640	7
22	1329	186	252		253	74	75	0.45 .671	1.50	1015.450	8
23	1331	186	252		254	74	74	0.45	1.50	1017.460	8
24	1333	184	252		255	73	74	0.355	0.65	1018.450	7
	1335									1020.030	-
	48	[illegible] Average				Average Average	Average 74	460	.725 Average	24.65 Total	

1·15 350

EOF

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Sample Calculation
Statistical Analysis

Acid Plant Tail Gas Stack
Particulate emission rate (lb/hr)

$x_1 = 27.0$ (Test 1) $N = 3$

$x_2 = 15.4$ (Test 2)

$x_3 = 11.7$

The mean ($\bar{x}$) for a set of N numbers, x_i, is given by:

$$\bar{x} = \frac{(\Sigma x_i)}{N}$$

$$x = (27.0 + 15.4 + 11.7)/3 = 18.0$$

The standard deviation (σ) for this set of numbers is given by:

$$\sigma = \sqrt{\lambda/(N - 1)}$$

$$\sigma = \sqrt{131.1/3 - 1 = 8.1}$$

$$\lambda = (\Sigma x_i^2) - N(\bar{x})^2$$

where

$$= (27^2 + 15.4^2 + 11.2^2) - 3(18.0)^2$$

$$\lambda = 131.1$$

The 90% confidence interval (CI) is approximated by:

$$\begin{aligned} CI &= T(\sigma/\sqrt{N}) \\ &= \left[c_1 + c_2\,(N - 1)^{c3}\right](\sigma/\sqrt{N}) \\ &= \left[1.645 + 2.605\,(3 - 1) - 1.186\right](8.1/\sqrt{3}) = 13.0 \end{aligned}$$

where

c_1, c_2, and c_3 are constants for $N \geq 3$:

For the 90% CI; $c_1 = 1.645$, $c_2 = 2.605$, $c_3 = -1.186$

The lower confidence limit (LCL) is given by:

$$\begin{aligned} LCL &= \bar{x} - CI \\ &= 18.0 - 13.0 = 5.0 \end{aligned}$$

The upper confidence limit (UCL) is given by:

$$\begin{aligned} UCL &= \bar{x} + CI \\ &= 18.0 + 13.0 = 31.0 \end{aligned}$$

Reference: EPA Report 600/8-76-002, "HP-65 Programmable Pocket Calculator Applied to Air Pollution Measurement Studies: Stationary Sources," Program APol-18.

APPENDIX C

PROCESS DATA

Received [illegible]

KENNECOTT COPPER CORPORATION
RAY MINES DIVISION
HAYDEN, ARIZONA 85235

April 13, 1977

Mr. Robert Larkin
Staff Engineer
ACUREX - Aerotherm
485 Clyde Ave.
Mountain View, Ca. 94042

Dear Mr. Larkin:

In your letter of March 21, 1977, you requested certain information regarding process feed rates. In my initial reply dated March 28, 1977, I addressed the problem of smelter feed rate as it applies to the allowable emissions rate calculations.

Following is the best available information in reply to your other queries using your item numbering system 2 through 5.

Item 2 - The August [illegible], 1976 entry on your enclosure 1 does show 207 dry tons charged. That was an error which occurred as a result of weightometer location and feed accounting problems. Actually, there was no feed to the fluo-solids roaster, but there was 207 tons of concentrate fed to the reactor feed bin preparatory to startup.

Item 3 - Again, the total feed to the smelter should be used for the allowable particulate emissions formula. Following is a breakdown of the total feed to the smelter for the periods in question:

	1976								
	Aug. 5	Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10	Aug. 11	Dec. 15	Dec. 16
Tons to Reactor	1029	1102	391	1126	1079	834	413	1528	1415
Tons Lime	39	41	17	44	37	27	16	15	33
Tons Converter Flux	288	72	109	77	234	248	128	330	58
Tons Fettling	39	29	29	27	54	81	25	39	10
Total Feed	1395	1244	546	1274	1404	1190	582	1912	1516

Item 4 - Following are best estimates for total material feed rates to the converters for December 15 and 16, 1976:

	12/15/76	12/16/76
Reverb Furnace Matte (Tons)	720	738
Converter Flux (Tons)	330	58
Total	1050	796

C-1-a

Item 5 - Following is the data requested for December 16, 1976:

1) Times that converter #2 and #3 were on finish:

Converter #2	Converter #3
1920 to 2035	0930 to 1045
2045 to 2120	1100 to 1330
2130 to 2145	
2205 to 2220	
2245 to 2320	

2) Circular chart indicating reactor feed rate. (Enclosure 1)

3) SO_2 strength received at the acid plant. (Enclosure 2)

4) Converter #2 and #3 blowing charts. (Enclosures 3 and 4)

5) Circular chart indicating tail gas SO_2 strength. (Enclosure 5)

Sincerely,

K. H. Matheson

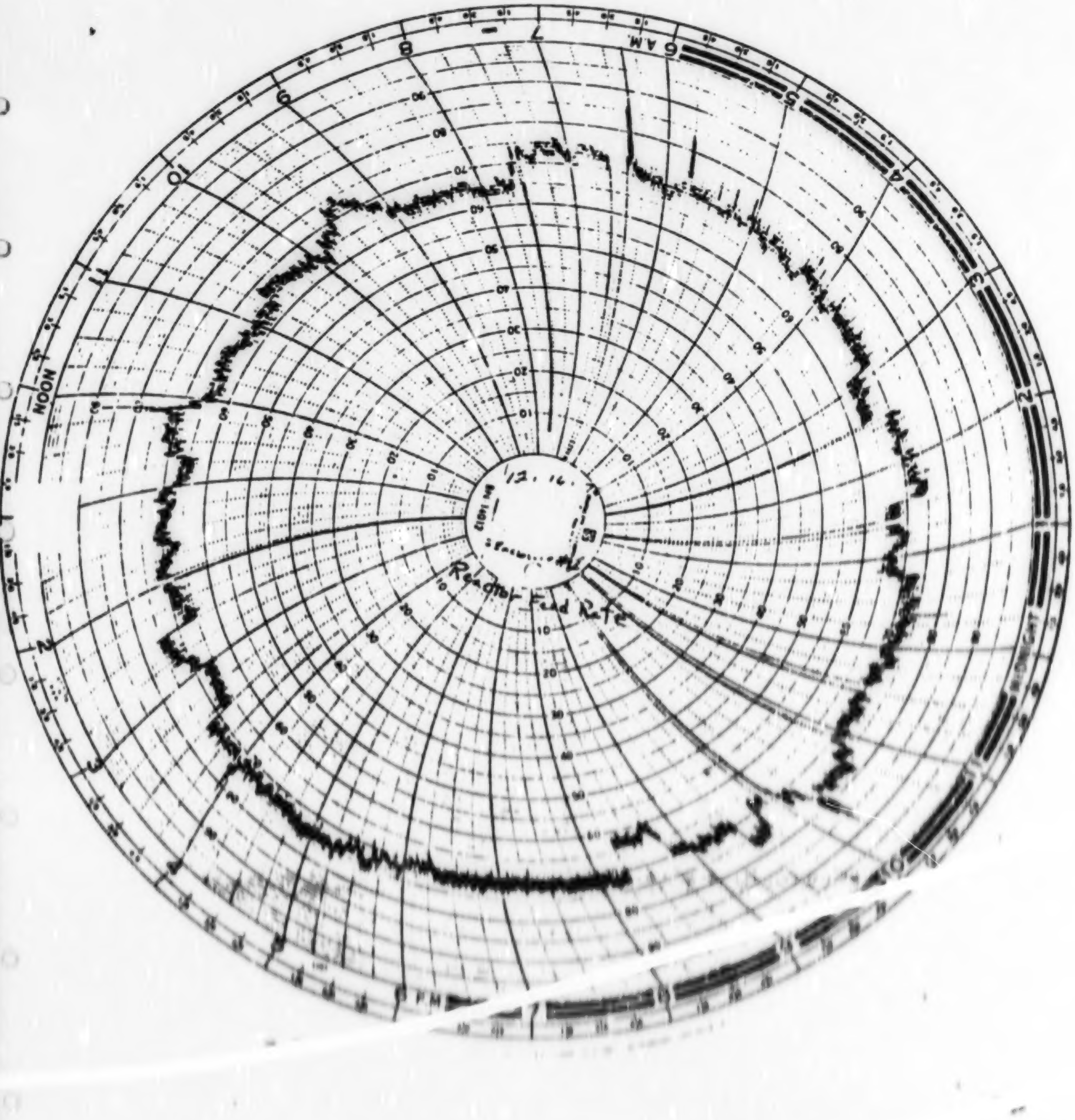
K. H. Matheson, Jr.
General Manager

KHM/CSF/es
Encl.

cc: J. T. Mortimer
J. S. Nebeker
J. E. Stocker
R. R. Peacock
F. L. Murray
C. S. Fitch

C-3

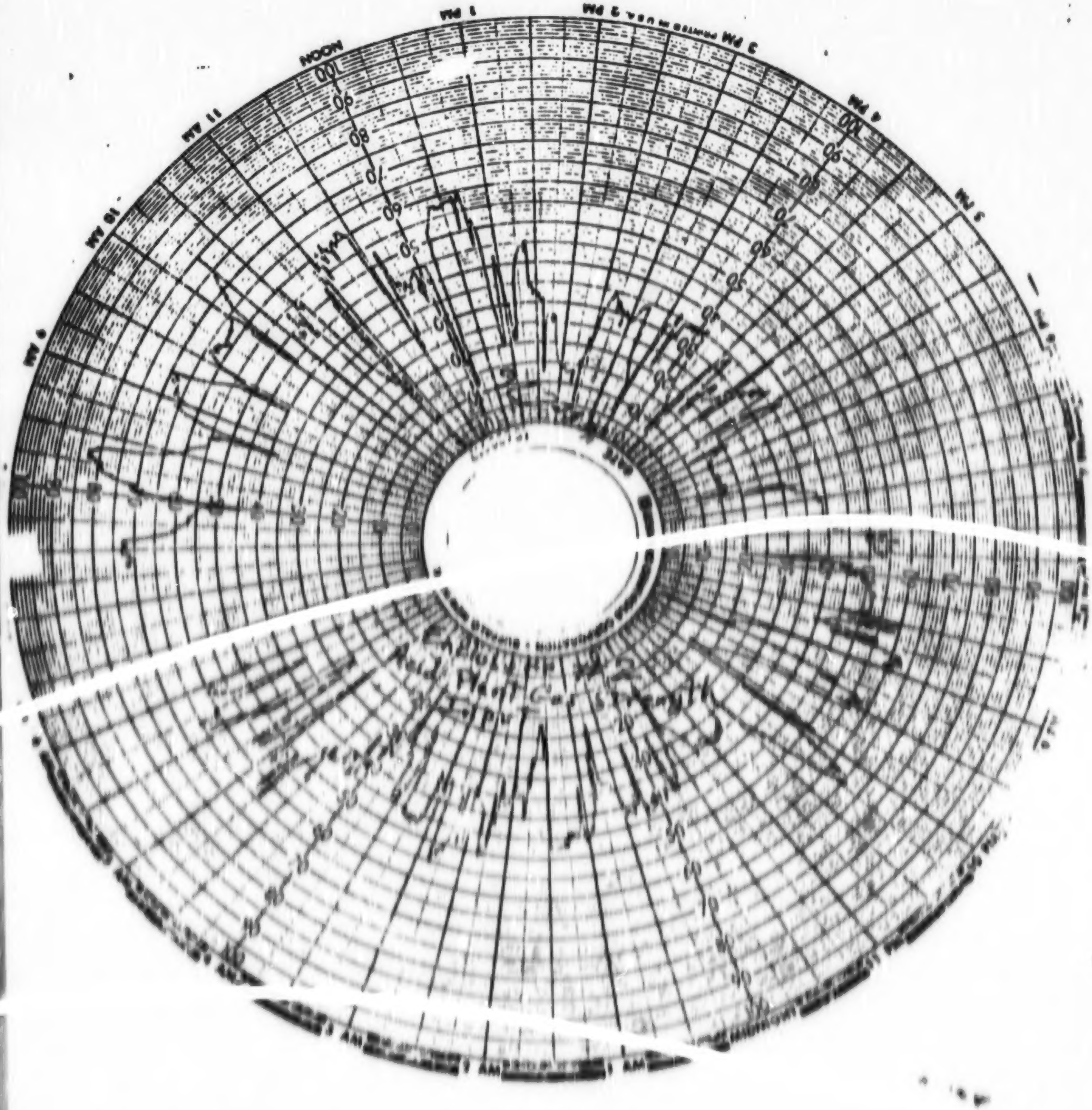
Reactor Feed
Approximate Tons Per Hour
12-16-76



Enclosure 1
4-13-77 letter

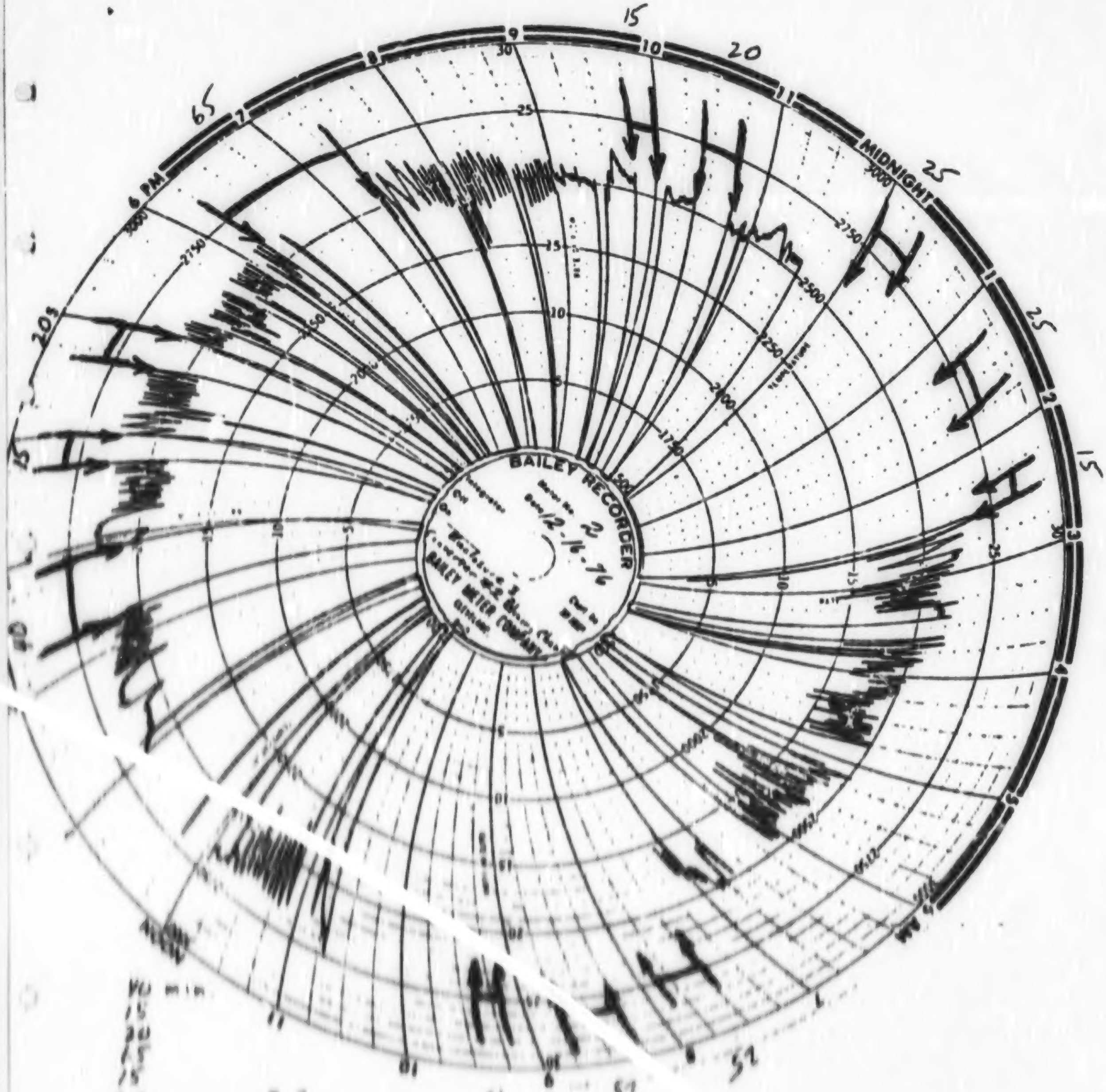
C-4 SO_2 strength of gas received at acid plant 0-10%

12-16-76



Enclosure 2

2 Converter Blowing Chart
12-16-76
temperature - °F



40 min.
15
20
15
15
20
25
25
15
25
25
15

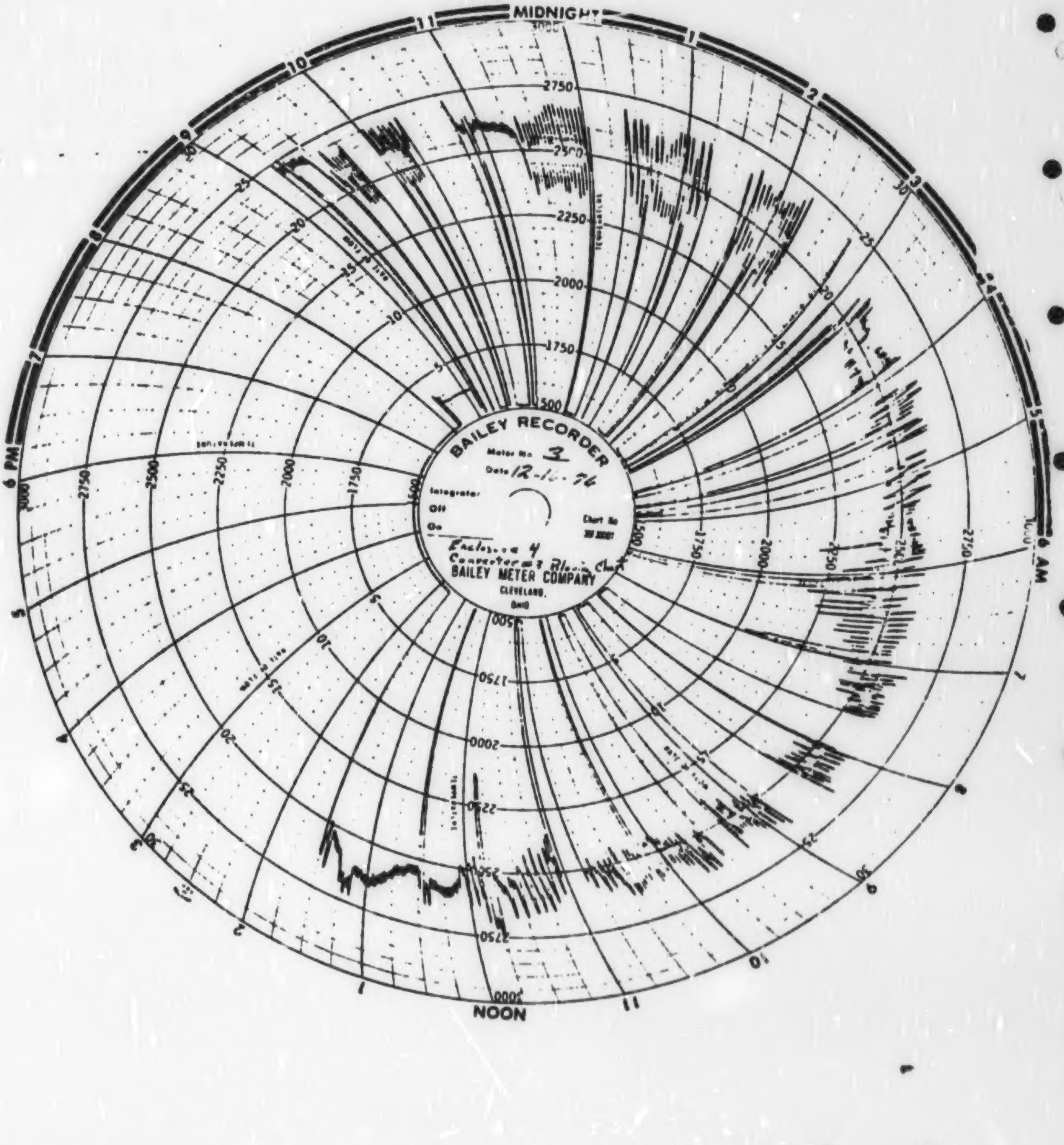
305 min = 5.08 hrs

∴ 18.92 hrs converter blowing on 12/16

Enclosure 3
4-13-77 letter

C-6

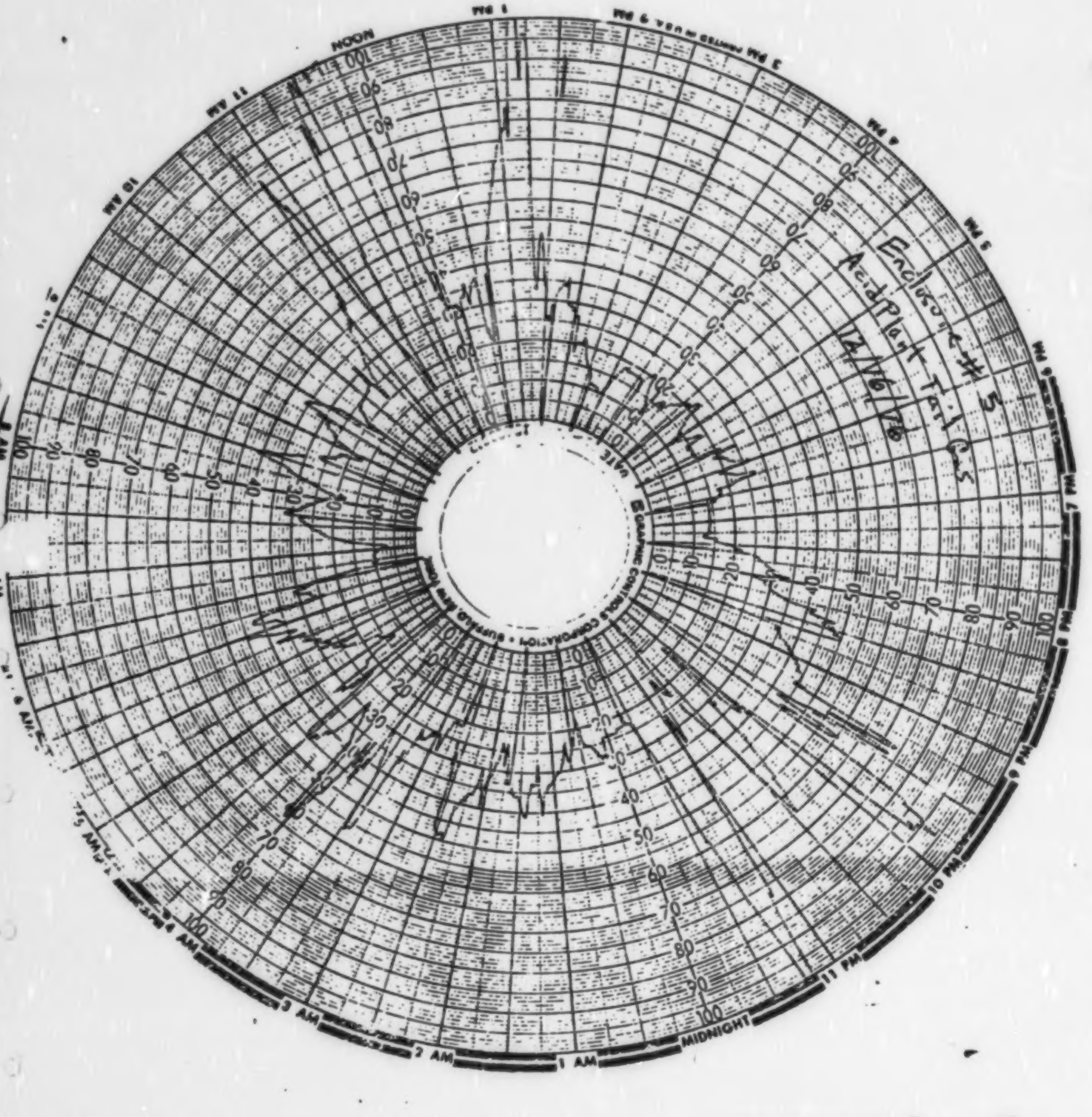
#3 Converter Blowing Charts
temperature - °F
12-16-76



Enclosure 4
4-13-77 letter

Tail Gas SO_2

scale: 0-100 % of full scale, full scale = 2000 ppm



Enclosure 5
4-13-77 letter

C-8

Enclosure 1

DATA FOR ENVIRONMENTAL CONTROL
- Provided by Kennecott

TE	Day Tons Charged	% S	Tons S	Reactor Operating Time
2	1313	[illegible]	375	22:40
3	207	[illegible]	58	0
4	747	[illegible]	220	11:10
5	1[illegible]5	[illegible]	329	18:30
6	1135	[illegible]	370	19:35
7	407	33.[illegible]	136	5:43
8	116[illegible]	[illegible]	399	21:30
9	1112	2[illegible].8	331	22:15
10	856	27.5	234	12:22
	8013	[illegible]	2455	
11				

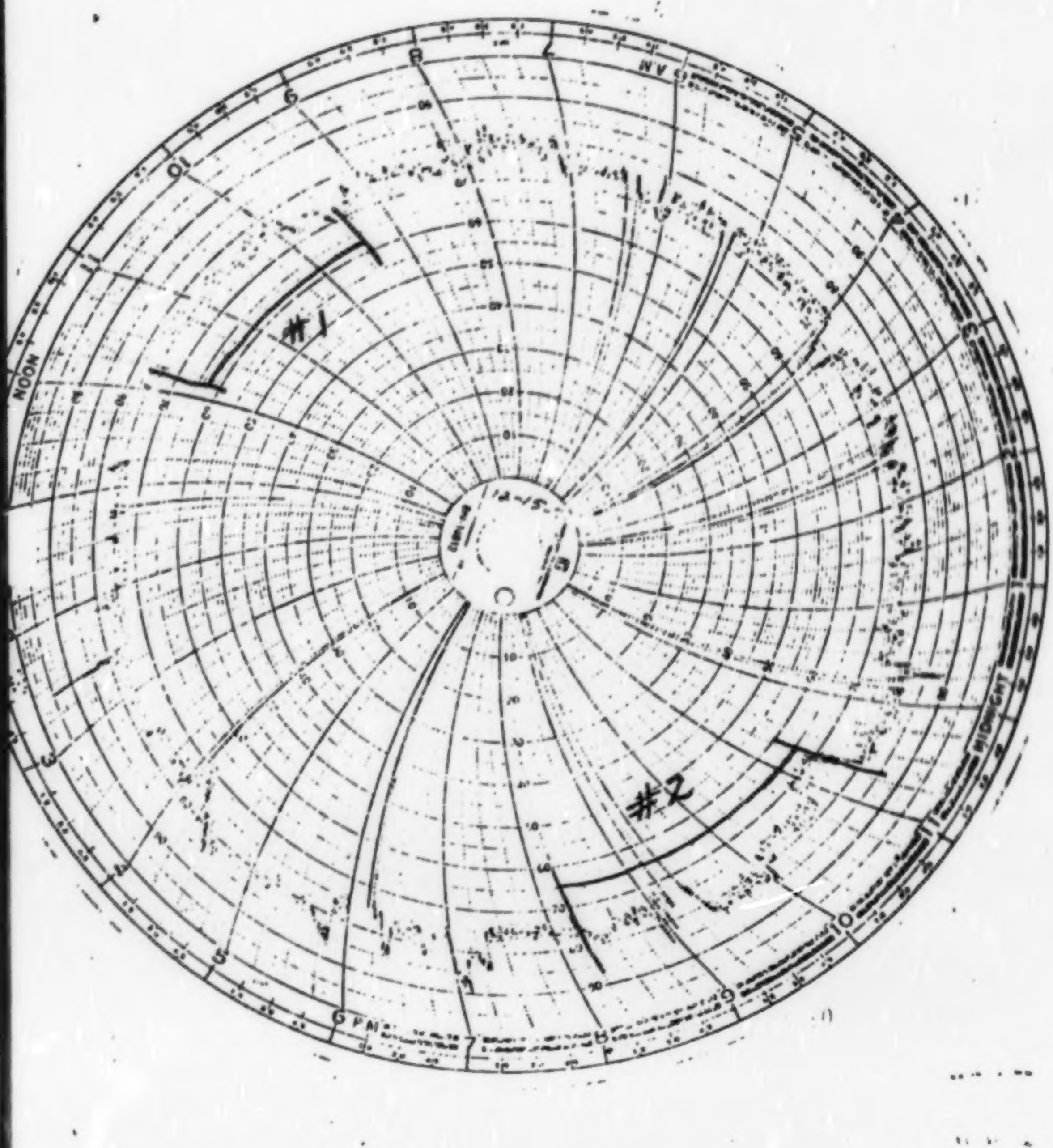
Reproduced from best available copy.

TIMES WHEN EACH CONVERTER WAS ON FINISH
- provided by Kennecott -

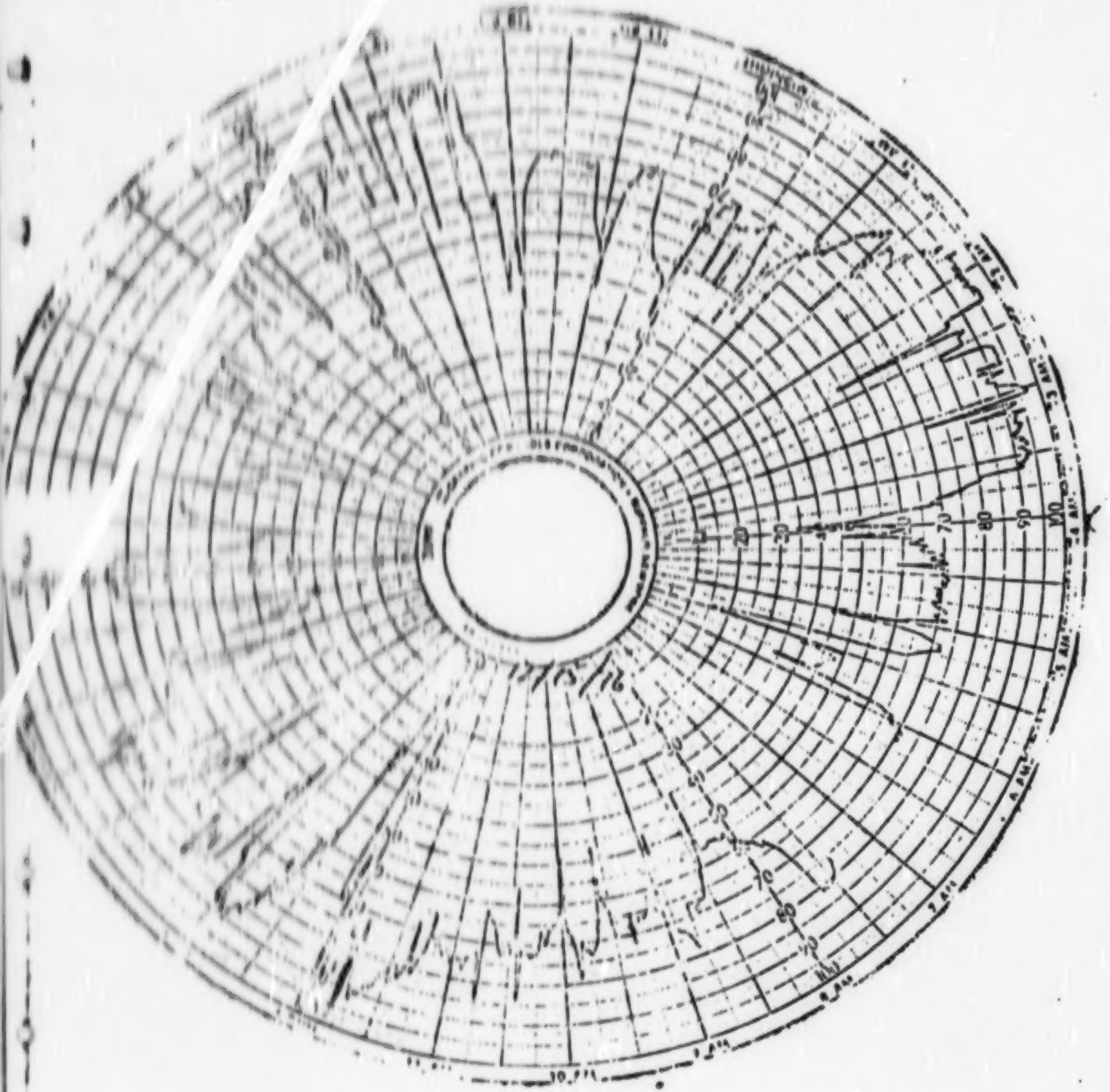
TIME	CONVERTER #	DATE
0430 - 0740	2	12/8/76
1400 - 1650	3	
0630 - 0925	3	12/9/76
1645 - 2010	2	
0640 - 1100	2	12/10/76
1430 - 1755	3	
0545 - 0855	3	12/11/76
1645 - 2040	2	
0900 - 1250	3	12/13/76
0840 - 1220	3	12/14/76
1855 - 2305	2	
1050 - 1550	2	12/15/76
1900 - 2050	3	

C-10

Reactor Feed
Approximate Tons Per Hour
12-15-76

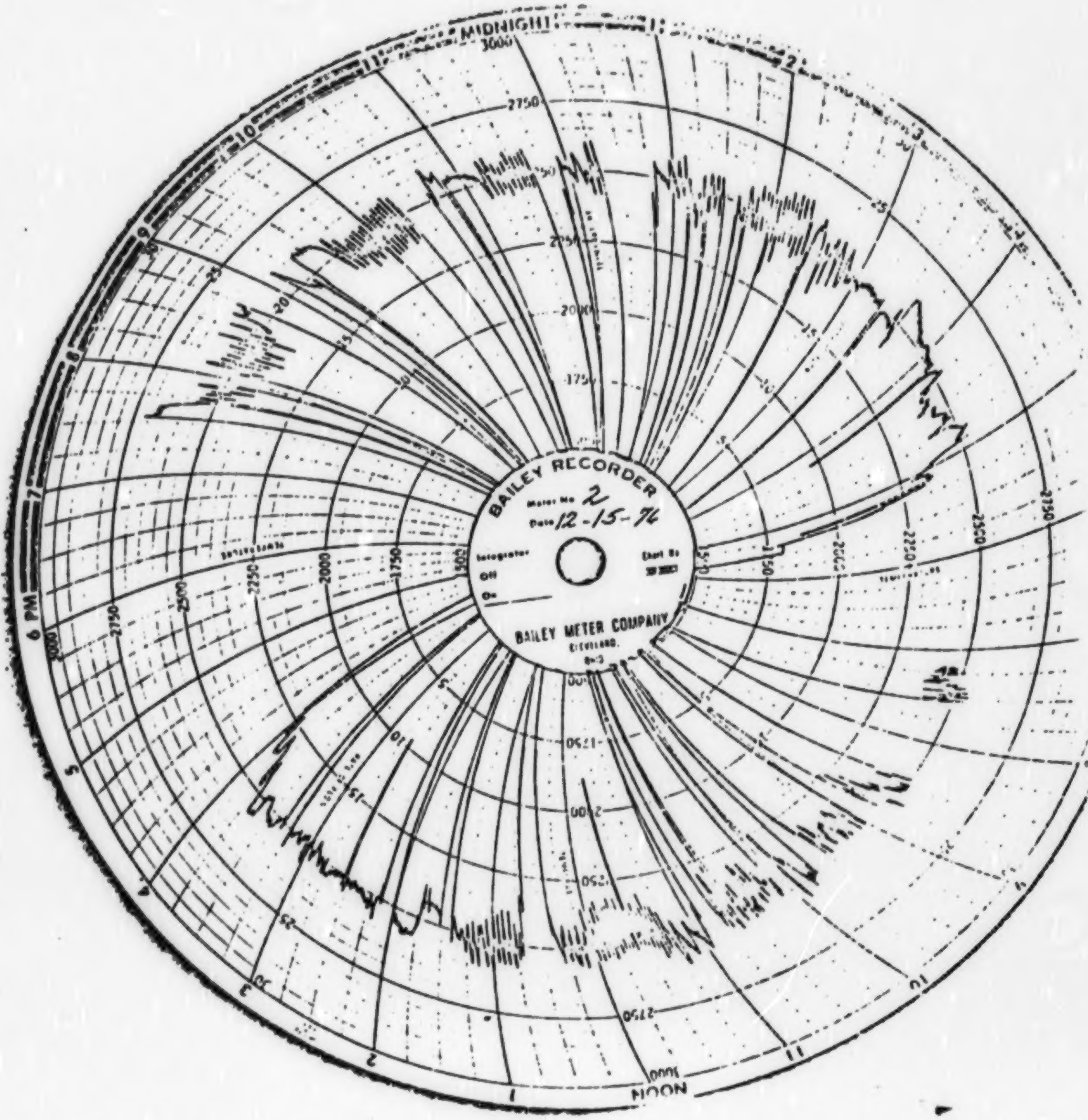


SO_2 strength at gas receiver
at acid plant 0-10%
12-15-76



C-12

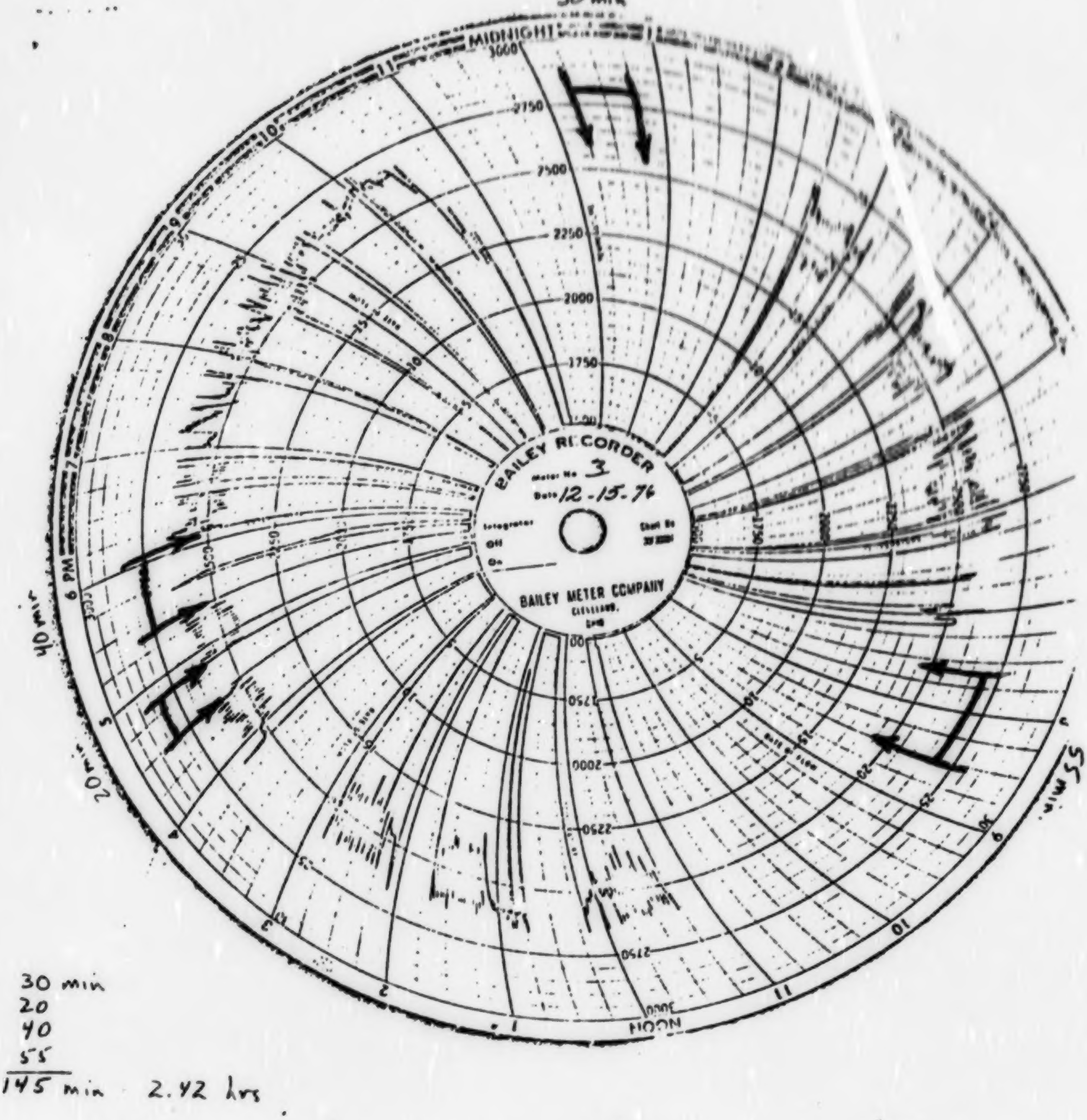
#2 Converter Blowing Chart
12-15-76
vs. temperature - °F



#3 Converter Blowing Charts

temperature - °F

12-15-76



30 min
20
40
55
145 min 2.42 hrs

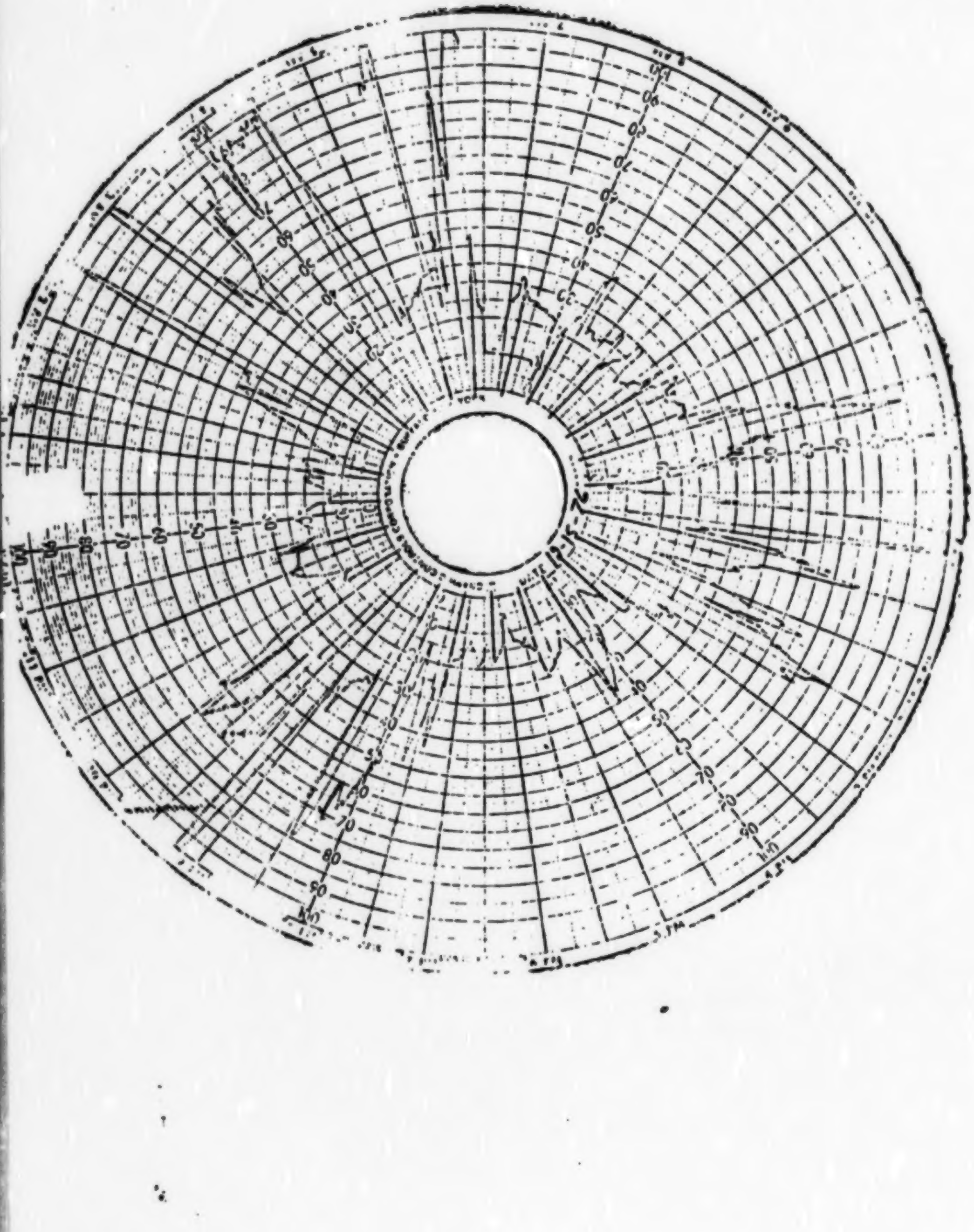
∴ 21.58 hrs converters blowing on 12/15

C-14

Tail Gas SO_2

scale: 0-100 % of full scale, full scale = 2000 ppm

12-15-76



APPENDIX D
CALIBRATION

CALIBRATION DATA FOR VALIDYNE DIFFERENTIAL PRESSURE TRANSDUCER

Calibration Pressure (psi)	Transducer[a] Output (MV/V)
0	0.0
+0.005	49.0
+0.01	100.0
+0.005	49.3
0	0
-0.005	49.8
-0.01	100.0
-0.005	49.9
0	0

[a] Calibrated as a system with CD12, S/N 12677

Model No.	DP103
Serial No.	21300
Range No.	±0.01 psi
Temp.	72°F
Date	7/8/76
Zero	608
Span	566

Date 7/6/76
Time 10:00
Barometric Pressure 29.99
Ambient Temperature 72

Orifice Meter Small Orifice (0.187)
Orifice Magnehelic 50523 PM50
Primary Calibration Meter DGM259453
Control Module 0.0039

Operators George Sutton, Ross Gilchrist
Wet Bulb Temperature

METER CALIBRATION DATA

Orifice Manometer ΔH_{ref} (in wg.)	Orifice Magnehelic ΔH_0 (in wg.)	Primary Meter ΔP_p (in wg.)	Dry Test Meter P_{dg} (in. wg.)	Gas Volume Primary Meter V_p (ft.³)	Gas Volume Dry Test Meter V_d (ft.³)	Temperature						Time t (min.)	γ	K_0
						Primary Meter			Dry Test Meter					
						Inlet, T_{pi} (°F)	Outlet, T_{po} (°F)	Avg., T_{pa} (°F)	Inlet, T_{di} (°F)	Outlet, T_{do} (°F)	Avg., T_{da} (°F)			
	0.2													
	0.4													
	0.6													
	0.8													
	1.0			432.634 438.076	74.996 80.499	72 73	72 72	72.25	70 72	70 71	70.75	10	1.015	0.697
	1.2													
	1.4													
	1.6													
	1.8													
1.98 ±0.02	2.0			438.076 444.245	80.499 86.690	73 73	72 72	72.5	72 74	71 71	72	8	1.009	0.699
	2.2													
	2.4													
	2.6													
	2.8													
	3.0			444.246 451.731	86.690 94.192	74 74	73 73	73.5	74 77	71 72	73.5	8	1.008	0.693
	3.2													
	3.4													
	3.6													
	3.8													
3.98 ±0.01	4.0			451.731 457.146	94.192 99.615	74 74	73 74	73.75	77 80	72 73	75.5	5	1.008	0.695
	4.2													
	4.4													
	4.6													
	4.8													
	5.0			457.146 463.235	99.615 105.688	74 75	73 74	74	80 83	72 73	77	5	0.995	0.700
													Average	
													1.007	0.697

Date 7/6/76

Time 11:00

Barometric Pressure 29.99

Ambient Temperature 72

Orifice Meter Small Orifice (0.187)

Orifice Magnehelic 50523 MH63

Primary Calibration Meter DGM259453

Control Module 0.0038

Operators George Sutton, Ross Gilchrist

Wet Bulb Temperature

METER CALIBRATION DATA

Orifice Manometer ΔH_{ref} (in.wg.)	Orifice Magnehelic ΔH_{D} (in.wg.)	Primary Meter ΔH_p (in.wg.)	Dry Test Meter P_{dg} (in. wg.)	Gas Volume Primary Meter V_p (ft.³)	Gas Volume Dry Test Meter V_d (ft.³)	Temperature						Time t (min.)	α	K_0
						Primary Meter			Dry Test Meter					
						Inlet, T_{pi} (°F)	Outlet, T_{po} (°F)	Avg., T_{pa} (°F)	Inlet, T_{di} (°F)	Outlet, T_{do} (°F)	Avg., T_{da} (°F)			
	0.2													
	0.4													
	0.6													
	0.8													
1.14	1.0			463.544 469.512	46.866 53.054	74 74	74 74	74	73 73	73 73	74	10	1.039	0.762
	1.2													
1.53 ±0.01	1.4													
	1.6													
	1.8													
2.12 ±0.01	2.0			469.512 475.955	53.053 59.714	74 75	74 74	74.25	77 80	74 76	76.75	8	1.033	0.727
	2.2													
2.52 ±0.02	2.4													
	2.6													
	2.8													
3.10 ±0.02	3.0			475.955 483.646	59.714 67.659	75 75	74 74	74.5	81 84	76 77	79.5	8	1.031	0.709
	3.2													
3.52 ±0.02	3.4													
	3.6													
	3.8													
3.92 ±0.02	4.0			483.646 489.169	67.660 73.358	75 76	74 74	74.75	84 86	77 77	81	5	1.030	0.706
	4.2													
	4.4													
	4.6													
	4.8													
	5.0			489.169 495.337	73.358 79.697	76 76	74 75	75.25	86 88	78 78	82.5	5	1.027	0.705
													Average	
													1.032	0.722

DATE 7/9/76 (7/13/76)
TIME 10:20 a.m. (7:30 a.m.)
BAROMETRIC PRESSURE 30.03 hg (29.90" hg)
AMBIENT TEMP

TEST PITOT TUBE 10' Reverb w/Filter
STANDARD PITOT TUBE United Sensor
TEST SECTION LOCATION Center
OPERATORS George Sutton

NOZZLE SIZE 7/16"
N PITOT SPACING 1-7/8"
PITOT ING 15/16"

PITOT TUBE CALIBRATION DATA

Test Pitot Tube ΔP (in. wg.)		Standard Pitot Tube ΔP (in. wg.)	C_p	Static Pressure (in. wg.)	Gas Temp (°F)	Wet Bulb Temp (F°)	Test Section Velocity (fps)
Upper Leg	Lower Leg						
0.44	0.45	0.30	0.817 0.808				
0.56	0.54	0.37	0.805 0.819				
0.72	0.70	0.47	0.805 0.811				
		7/13/76					
0.5	0.5	0.33	0.804 0.804				
0.66	0.65	0.44	0.808 0.814				
0.78	0.8	0.52	0.808 0.798				
0.94	0.93	0.63	0.810 0.815				
1.08	1.06	0.70	0.797 0.804				
1.32	1.29	0.89	0.813 0.822				
1.20	1.18	0.79	0.803 0.810				

Average $C_{p,\ upper}$ = 0.808

Average $C_{p,\ lower}$ = 0.811

DATE 7/12/76

TIME 9:25 a.m.

BAROMETRIC PRESSURE 29.99" Hg

AMBIENT TEMP 74

TEST PITOT TUBE 10' Reverb w/o Filter

STANDARD PITOT TUBE United Sensor

TEST SECTION LOCATION Center

OPERATORS George Sutton

NOZZLE SIZE 7/16"

NOZZLE-PITOT SPACING 25/32"

PITOT-TC SPACING 15/16"

PITOT TUBE CALIBRATION DATA

Test Pitot Tube ΔP (in. Hg.)		Standard Pitot Tube ΔP (in. wg.)	C_p	Static Pressure (in. wg.)	Gas Temp (°F)	Wet Bulb Temp (F°)	Test Section Velocity (fps)
Upper Leg	Lower Leg						
0.50	0.50	0.31	0.779 0.779				
0.59	0.60	0.37	0.781 0.777				
0.70	0.70	0.44	0.785 0.785				
0.79	0.78	0.51	0.795 0.800				
0.88	0.88	0.56	0.787 0.787				
1.1	1.05	0.66	0.770 0.785				
1.25	1.30	0.80	0.793 0.777				
1.50	1.53	0.94	0.784 0.776				

Average $C_{p,\ upper}$ = .785

Average $C_{p,\ lower}$ = 0.784

DATE Oct. 6, 1976
TIME 7:45
BAROMETRIC PRESSURE 30.05
AMBIENT TEMP 56°F

TEST PITOT TUBE 10' Probe #1
STANDARD PITOT TUBE United Sensor
TEST SECTION LOCATION Center
OPERATORS R. Gilchrist

NOZZLE SIZE 1/4"
NOZZLE-PITOT SPACING 7/8"
PITOT-TC SPACING 7/8"

PITOT TUBE CALIBRATION DATA

Test Pitot Tube ΔP (in. wg.)		Standard Pitot Tube ΔP (in. wg.)	C_p	Static Pressure (in. wg.)	Gas Temp (°F)	Wet Bulb Temp (F°)	Test Section Velocity (fps)
Upper Leg	Lower Leg						
0.09	0.09	0.05	0.745 0.745				
0.25	0.25	0.16	0.800 0.800				
0.40	0.40	0.26	0.806 0.806				
0.56	0.57	0.35	0.791 0.784				
0.72	0.73	0.44	0.782 0.776				
0.94	0.93	0.57	0.779 0.783				
1.06	1.06	0.65	0.783 0.783				
1.25	1.24	0.75	0.775 0.778				
1.47	1.46	0.87	0.769 0.772				
1.61	1.60	0.96	0.772 0.775				

Average $C_{p,\ upper}$ = .780

Average $C_{p,\ lower}$ = .780

Average C_p with nozzle = 0.780

Date 8/26
Time 15:30
Barometric Pressure 30.02
Ambient Temperature 77

Orifice Meter small
Orifice Magnehelic 41112NH18
Primary Calibration Meter 259453
Control Module 0017

Operators Knirck
Wet Bulb Temperature

METER CALIBRATION DATA

Orifice Manometer ΔH_{ref} (in.wg.)	Orifice Magnehelic $\Delta H_@$ (in.wg.)	Primary Meter ΔH_p (in.wg.)	Dry Test Meter P_{dg} (in. wg.)	Gas Volume Primary Meter V_p (ft.³)	Gas Volume Dry Test Meter V_d (ft ³)	Temperature						Time t (min.)	γ	K_0
						Primary Meter			Dry Test Meter					
						Inlet, T_{pi} (°F)	Outlet, T_{po} (°F)	Avg., T_{pa} (°F)	Inlet, T_{di} (°F)	Outlet, T_{do} (°F)	Avg., T_{da} (°F)			
	0.2													
0.4	0.4			5.059	5.023	79 79	79 79	79	76 78	76 78	77	15	.998	0.678
	0.6													
	0.8													
1.02	1.0			5.234	5.221	79 79	79 79	79	78 79	78 78	78	10	1.001	0.666
	1.2													
	1.4													
	1.6													
	1.8													
2.08	2.0			7.415	7.395	79 79	79 79	79	80 81	79 79	79.5	10	1.001	0.668
	2.2													
	2.4													
	2.6													
	2.8													
3.08	3.0			7.143	7.110	79 79	79 79	79	81 82	79 79	80	8	1.000	0.657
	3.2													
	3.4													
	3.6													
	3.8													
4.0	4.0			8.161	8.102	77 77.5	77 77.5	77.5	75 77	75 77	76	8	1.005	0.653
	4.2													
	4.4													
	4.6													
	4.8													
	5.0													

Average	
1.001	0.664

APPENDIX E

LABORATORY PARTICULATE WEIGHT DATA — REVERBERATORY FURNACE MAIN STACK

WEIGHT VERSUS TIME CURVE FOR GLASS FIBER FILTER

The particulate matter caught on the glass fiber filters on the reverberatory furnace main stack was very hygroscopic in nature and could not be weighed directly. Instead a weight versus time curve was prepared for each filter. Basically, two curves were prepared for each filter — one curve illustrating the change in weight during the initial few minutes of exposure to ambient conditions inside the analytical balance's weighing chamber, and a second curve illustrating the long term changes in weight. Figures B-1 and B-2 illustrate two typical curves.

Examining the data in Figure B-1, it can be seen that as soon as the filter is exposed to the ambient air, its weight starts to change very rapidly due to adsorption of water vapor onto the surface of the hygroscopic particulate matter. It took ~10 to 20 seconds for the analyst to adjust the dials on the balance to get the first weight reading. Several more readings were taken over the next few minutes to accurately plot the shape of the curve so that it could be extrapolated to zero time which presumably is the true weight of the filter and particulate without the presence of any uncombined water. Several more readings were then taken over an extended period of time to determine the equilibrium weight which the filter eventually reached. From Figure B-2, it can be seen that it took ~6 to 8 hours for the filter weight to level off at an equilibrium value.

It is important to note that the definition of particulate matter does not include uncombined water and hence, the extrapolated weight is considered the true weight and used in the emission rate calculations.

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FILTER, PARTICULATE AND RESIDUE WEIGHT DATA
REVERBERATORY FURNACE MAIN STACK
EXTRAPOLATED WEIGHT

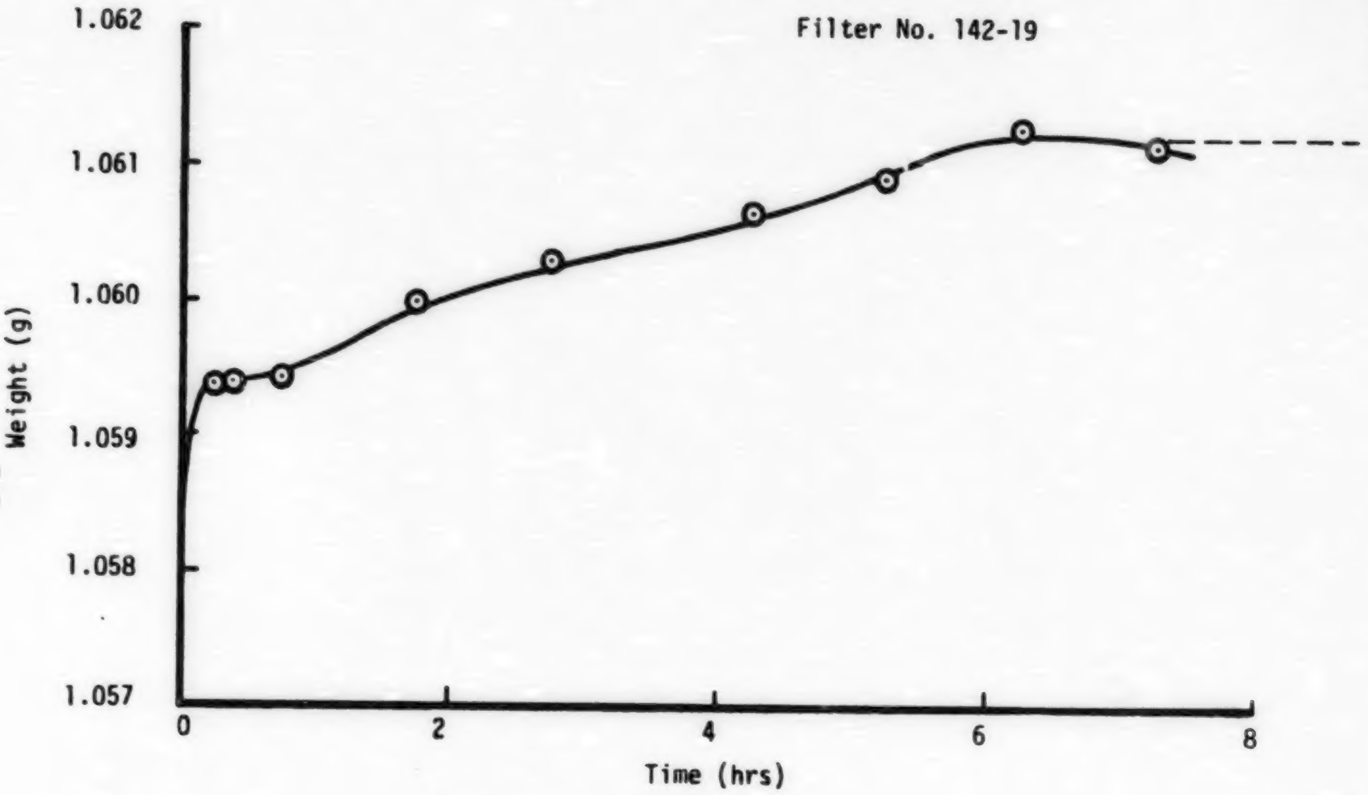
Test	Filter Number	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	Total Weight (mg)
1	142-45	1017.33	1102.44	85.11	90.85	175.96
2	142-37	1006.90	1163.85	156.95	92.54	249.49
3	142-29	1013.64	1111.10	97.46	32.71	130.17
4	142-19	1019.11	1056.33	37.22	46.48	83.70
5	142-30	1011.79	1045.58	33.79	27.32	61.11
6	142-18 (outstack)	1015.25	1037.90	22.65	23.19	87.25
	5	127.75	139.05	11.30		
	3 (instack)	126.75	133.58	6.83		
	6	126.17	134.58	8.41		
	4	126.95	141.82	14.87		
7	142-34 (outstack)	1014.93	1031.74	16.81	93.44	211.34
	15	127.57	133.30	5.73		
	18 (instack)	125.78	133.40	7.62		
	7	128.97	208.30	79.33		
	16	125.78	134.19	8.41		

FILTER, PARTICULATE AND RESIDUE WEIGHT DATA
REVERBERATORY FURNACE MAIN STACK
EQUILIBRIUM READING

Test	Filter Number	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	Total Weight (mg)
1	142-45	1017.33	1168.58	151.25	90.85	242.21
2	142-37	1006.90	1230.85	223.95	92.54	316.49
3	142-29	1013.64	1178.25	164.61	32.71	197.32
4	142-19	1019.11	1061.27	42.16	46.48	88.64
5	142-30	1011.79	1047.78	35.99	27.32	63.31
6	142-18 (outstack)	1015.25	1044.80	29.55	23.19	102.45
	5 (instack)	127.75	141.80	14.05		
	3	126.75	134.80	8.05		
	6	126.17	136.35	10.18		
	4	126.95	144.88	17.43		
7	142-34 (outstack)	1014.93	1035.58	20.65	93.44	229.82
	15 (instack)	127.57	135.68	8.01		
	18	125.78	136.37	10.59		
	7	128.97	215.58	86.61		
	16	125.78	136.30	10.52		

FILTER, PARTICULATE AND RESIDUE WEIGHT DATA
REVERBERATORY FURNACE MAIN STACK
FIRST READING

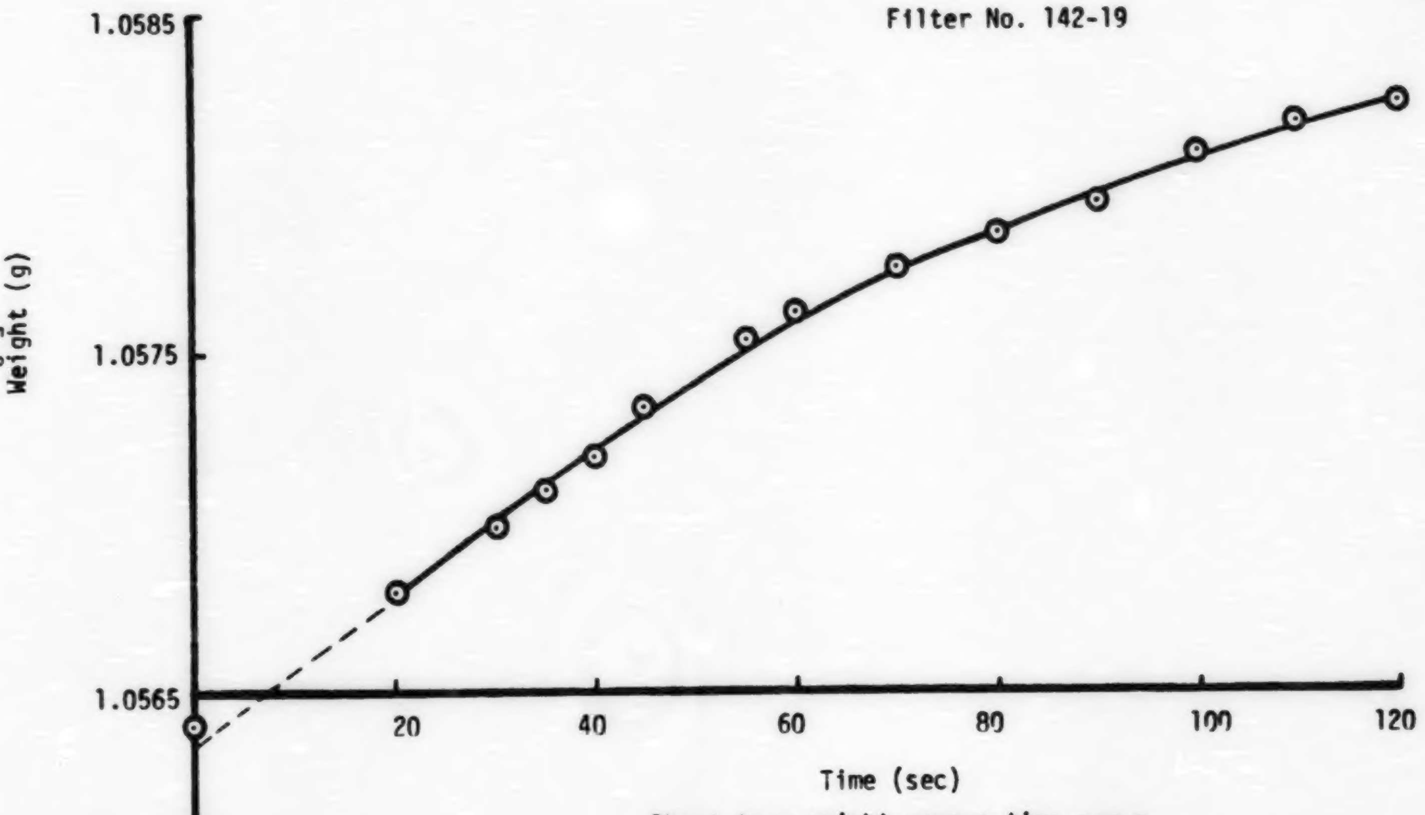
Test	Filter Number	Tare Weight (mg)	Dust & Filter Weight (mg)	Dust Weight (mg)	Residue Weight (mg)	Total Weight (mg)
1	142-45	1017.33	1108.00	90.70	90.85	181.55
2	142-37	1006.90	1166.00	159.10	92.54	251.64
3	142-29	1013.64	1114.00	100.39	32.71	133.07
4	142-19	1019.11	1056.80	37.69	46.48	84.17
5	142-30	1011.79	1046.00	34.21	27.32	61.53
6	142-18 (outstack)	1015.25	1040.00	24.75	23.19	91.12
	5 (instack)	127.75	140.00	12.25		
	3	126.75	133.80	7.05		
	6	126.17	135.00	8.83		
	4	126.95	142.00	15.05		
7	142-34 (outstack)	1014.93	1032.00	17.07	93.44	214.61
	15 (instack)	127.57	134.20	6.63		
	18	125.78	134.00	8.22		
	7	128.97	209.50	80.53		
	16	125.78	134.50	8.72		



Long term weight versus time curve

A-17957

A17956



Short term weight versus time curve